Appendix K

Ichthyoplankton Assessment

Appendix K-1

Ichthyoplankton Assessment

Environmental Report
in support of the
Port Ambrose Deepwater Port License Application

January 2014

Topic Report 4 – Biological Resources

Appendix D (Revised)

ICHTHYOPLANKTON ENTRAINMENT ASSESSMENT

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1. Introduction

This document presents the ichthyoplankton assessment model, assumptions, and data used to calculate potential impacts on fish eggs and larvae associated with seawater intake during construction, operation (including emergency actions and maintenance) and decommissioning of the Port Ambrose Project (the Project). This assessment estimates potential impacts to fisheries from impingement and entrainment (I & E) at the facility. Impingement occurs when fish or other aquatic life are trapped on intake screens as a result of the force of the intake water. Entrainment occurs when smaller organisms such as fish eggs and larvae enter the system as part of the intake water.

This revised version of the report is intended to supersede the previous version (Volume II, Topic Report 4, Appendix D Ichthyoplankton Entrainment Assessment, September 2012) as included in the Port Ambrose Deepwater Port application. In response to agency comments and data requests, this revision now addresses source data that is more site-specific to the Project (5-mile radius versus 50+ mile radius), and expands the scope to include intakes from all phases of the Project (construction, operation, emergencies/maintenance, and decommissioning versus just operations). The detailed assumptions and basis for these additional intakes are included in this report as Appendix A.

The Port Ambrose facility has the potential to have impacts to fisheries associated with the seawater intake due to entrainment. Impingement impacts from the facility are not likely due to the low design intake velocity proposed. The U.S. Environmental Protection Agency (EPA) has determined that an intake velocity of less than 0.5 foot per second (fps) allows most small fish to swim away from the intake (EPA 2002). Since the Port Ambrose facility will have an intake velocity of less than 0.5 fps during construction, operation (including emergency actions and maintenance) and decommissioning, the focus of this assessment is on entrainment impacts.

The entrainment calculations were performed following the National Oceanic and Atmospheric Administration (NOAA)/United States Coast Guard (USCG) jointly developed ichthyoplankton methodology as described in the ichthyoplankton assessment model appended to the Gulf Landing Final Environmental Impact Statement (EIS) (USCG and MARAD 2005a).

The entrainment modeling involves estimation of the:

- density of eggs and larvae in the intake water along the pipeline route (mainline) and at the location of the mooring buoys (port);
- historic densities of eggs and larvae within 5 miles of the mainline and port;
- numbers of organisms entrained based on estimated density and volume flow over one year;
- natural mortality rate that the entrained organisms would have otherwise undergone before reaching one year of age (i.e., estimation of Age-1 equivalents); and
- equivalent fishery yield.

Based on the modeling results and landings data, a value is estimated for the fish that may be entrained. Uncertainty in the assessment is then discussed, a sensitivity analysis is performed, and the overall results of the entrainment assessment are summarized.

2. Species Represented

All species of fish represented in historic data records from the Marine Resources Monitoring Assessment Program (MARMAP) and Ecosystem Monitoring Program (ECOMON) database (NMFS

3013) collected within 5 miles of the mainline or port locations were included in the analysis. The database groups some species by family or genus, perhaps due to difficulty in differentiating species at young life stages. Species listed as unknown were not included in the analysis but generally represented a small percentage of the total catch. Unknown egg species represented 18% of the total catch within 5 miles of the mainline and 3.9% of the total catch within 5 miles of the port. Unknown larval species were less than 1% of the total catch at both the mainline and port locations. Life history parameters for the fish species included are presented in Table 1. The total list of species evaluated includes the following:

- Anchovy (*Engraulidae sp.*)
- Physcid hakes (red hake) (*Urophycis*)
- Spotted codling (hake) (*Urophycis regia*)
- Fourbeard rockling (*Enchelyopus cimbrius*)
- Silver hake (*Merluccius bilinearis*)
- Bluefish (*Pomatomus saltatris*)
- Atlantic croaker (*Micropogonias undulates*)
- Cunner (*Tautogolabrus adspersus*)
- Atlantic mackerel (*Scomber scombrus*)
- Butterfish (*Peprilus triacanthus*)
- Searobin (*Prionotus sp.*)
- Sand lance (*Ammodytes sp.*)
- Lefteye flounders (*Bothidae sp.*)
- Gulfstream flounder (*Citharichthys arctifrons*)
- Smallmouth flounder (*Etropus microstomus*)
- Fourspot flounder (Hippoglossina oblonga)
- Summer flounder (*Paralicthys dentatus*)
- Yellowtail flounder (*Limanda ferruginea*)
- Windowpane flounder (*Scophthalmus aquosus*)
- Flounder sp (*Citharichthys*)

Table 1 – Life History Characteristics of Eggs and Larvae of Selected Species[1]

Species	Species	Zone Where Planktonic Stages are Present[2]		Duration of Planktonic Stages[2]		Adult Guild[3]
		Eggs	Larvae	Eggs	Larvae	
anchovy	*Engraulidae sp.*	Spawning concentrated near surface; in the Mid-Atlantic, spawning generally occurs in estuarine waters and may occur out to the edge of the continental shelf; 10-200 meters	larvae move upstream to waters with <10 ppm salinity shortly after hatching; located in upper portions of water column	peak abundance May-August	peak abundance July - August	Planktivore
Physcid hakes (red hake)	*Urophycis sp.*	Spawning occurs from May-November in inner shelf and marine parts of coastal bays with peaks in June-July	Inner to mid shelf in 10-200 meters; upper water column; May-December	hatch in 3-7 days, December-November with peaks in June and July	2 months, May-December with peak in September-October	Shrimp/small fish eater
Spotted codling (hake)	*Urophycis regia*	Pelagic	Pelagic	Summer to fall	Summer to fall	Amphipod/shrimp eater
Fourbeard rockling	*Enchelyopus cimbrius*	Pelagic eggs	Lavae are pelagic until ~ 5 cm, after which they become benthic	Hatching occurs around 1.6 – 2.4 mm	Larvae are pelagic until ~ 5 cm	Benthivore
Silver hake	*Merluccius bilinearis*	Pelagic; year round with peak between May and October	Mid to upper water column; descent to bottom at sizes of 17-20 mm	Hatching occurs at 2.6 – 3.5 mm	Descent to bottom at 17 – 20 mm; full fin development around 22 mm	Piscivore
bluefish	*Pomatomus saltatris*	Pelagic; across continental shelf but primarily in mid-shelf; spawn in spring Hatteras to Canaveral and in the summer from Hatteras to New England	near surface, rarely >15m; mid-shelf	hatch in 46-48 hours; May-August	1-2 months; most common July-August	Piscivore
Atlantic croaker	*Micropogonias undulates*	Pelagic	Drift in current until ultimately settling on soft bottoms of estuaries	Late summer to mid-fall	Late summer to mid-fall	Bentivore

Species	Species	Zone Where Planktonic Stages are Present[2]		Duration of Planktonic Stages[2]		Adult Guild[3]
		Eggs	Larvae	Eggs	Larvae	
Cunner	*Tautogolabrus adspersus*	Pelagic surface waters	Primarily in upper water column, eventually migrating to bottom waters	Eggs hatch in 42-45 hours at 20-22^{o}C	New hatchlings are 2-2.2 mm long	Benthivore
Atlantic mackerel	*Scomber scombrus*	Pelagic (10-325m depth); offshore majority shoreward side of shelf; most abundant May-June	Offshore; most abundant in June in New England; 10-130m depth - most found <50m	Spawns mid-April - June; hatch in 3-8 days	2 months; highest abundance southern New England in June	Planktivore
butterfish	*Peprilus traiacanthus*	Pelagic and buoyant; generally spawn offshore and at night; found on edge of continental shelf in spring then moving closer to shore as temperatures increase	Pelagic; occurs from outer shelf to high salinity parts of estuaries; most collected in waters <120m deep; collected in surface waters	spawns May-October, most abundant in July; hatch in 2-3 days	Most abundant July - August	Planktivore
Searobin	*Prionotus sp.*	Buoyant eggs; estuarine habitats	Late spring to fall with August peaks	Eggs found in water column for up to 35 days after spawning	Settlement between 24 and 35 days	Benthivore
Sand lance	*Ammodytes sp.*	Spawning occurs inshore between November and March; pelagic	Pelagic until roughly 2-3 months when reach a size of ~35 mm and become semi-demersal	Eggs hatch November – May with temperatures below 9^{o}C	2 – 3 months until reaching ~35mm	Planktivore
Lefteye flounders	*Bothidae* spp.	Variable based on species	Variable based on species	Variable based on species	Variable based on species	Variable based on species
Gulfstream flounder	*Citharichthys arctifrons*	Spring through summer; eggs are demersal	Larvae remain benthic	No information available	No information available	Benthivore

Species	Species	Zone Where Planktonic Stages are Present[2]		Duration of Planktonic Stages[2]		Adult Guild[3]
		Eggs	Larvae	Eggs	Larvae	
Smallmouth flounder**	*Etropus microstomus*	Nearshore; summer to fall; eggs demersal	Surface waters until an age of ~3 months	Pelagic; found mostly in surface waters	Migrate from pelagic stage to bottom dwelling after about 3 months	Benthivore
Fourspot flounder	*Hippoglossina oblonga*	Found in surface waters from May until mid-July	Surface waters until an age of ~3 months	Pelagic; found mostly in surface waters	Migrate from pelagic stage to bottom dwelling after about 3 months	Piscivore
summer flounder	*Paralicthys dentate*	Pelagic and buoyant; spawning occurs in open ocean; eggs found at depths of 30-70m in fall, as deep as 110m in winter and10-30m in spring	Commonly found 19-83 km from shore at depths of 10-70m between September - February	Spring to fall; heaviest concentration within nine miles of shore off New Jersey and New York	Metamorphosis occurs at 8-18mm; spring at depths of 10-30 meters	Piscivore
Yellowtail flounder	*Limanda ferruginea*	Surface water with water depths of 30-90 meters; temperature below 15°C	Surface water with water depths of 10-90 meters; temperature below 17°C	Mid-March – July with peaks in April – June	March – April in the New York Bight	Benthivore
Windowpane flounder	*Scophthalmus aquosus*	Surface waters with at depths <70 meters and temperatures below 20°C	Surface waters with at depths <70 meters and temperatures below 20°C	February – November with peaks in May – October	February – November with peaks in May - October	Amphipod/ Shrimp eaters
Flounder**	*Citharichthys spp.*	Spring through summer; eggs are demersal	Larvae remain benthic	No information available	No information available	Benthivore

[1]Sources: Essential Fish Habitat Source Documents by species *Life History and Habitat Characteristics* (NOAA 1999 - 2006) and Morton (1989).
[2]Species information assumed from other similar species when no specific information could be located.
[3]Guild information from Garrison and Link (2000).

3. Intake Volumes and Assumptions

In order to estimate the number of fish eggs and larvae entrained by construction and operation of the facility, estimates of the volume of water that will be withdrawn for each phase of the Project are necessary. Water use on an annual basis was used for evaluation of entrainment during each phase of the project. Operations and emergency/maintenance water use were combined during the entrainment assessment as they potentially impact the same affected area (port) over the same operational time frame. Estimated volumes are presented in Table 2. A complete discussion of water use during all phases of the Project is discussed in detail in Volume II Topic Report 3 Water and Sediment Quality, and supplemental information provided in Appendix A.

Table 2 – Annual Water Use for the Port Ambrose Facility over Project Life

Phase	Volume (M^3/year)	Intake / Discharge point	MARMAP/ECOMON data used
Construction	8,462,497	Mainline	Within 5 miles of Mainline
Operation	4,419,420	Port	Within 5 miles of Port
Emergency/Maintenance	86,688	Port	Within 5 miles of Port
Total Operation + Emergency/Maintenance	4,506,108	Port	Within 5 miles of Port
Decommissioning	494,653	Mainline	Within 5 miles of Mainline

3.1 Construction

Entrainment impacts to ichthyoplankton during the construction phase of the project may occur as a result of water withdrawn by construction vessels and water withdrawn for hydrostatic testing of the pipeline and buoy system. Hydrostatic test water will be withdrawn through screens and the intake velocity will be less than 0.5 foot per second. Construction volume also includes potential intake for commissioning of the port and LNGRVs.

3.2 Operation

During normal operations at the Port, when the LNGRV is connected to a buoy in regasification mode, seawater will be withdrawn for use as ballast water to replace the weight of the LNG offloaded from the vessel. While ballast water intake rates will vary during the offloading process, the intake velocity will remain below 0.5 fps and the average annual water intake is expected to be approximately 2,663,040 m^3/yr.

Seawater from the ballast water tanks will also be used as a source of cooling water for the engines and auxiliary cooling systems. This water will be recycled through the ballast water tanks, so there will be no discharge of cooling water at the Port. Sufficient storage tank capacity will be provided on the LNGRV so that there will also be no sanitary (black water) or hoteling (gray water) discharges while the vessel is stationed at the buoy.

Withdrawal for ballast water intake will occur through two sea chests located at approximately 20 feet (6 m) and 32 feet (10 m) below the waterline (when the vessel is approximately 50 percent offloaded, or at “half cargo”). The low sea chest intake screens will be located near the bottom of the vessel’s hull in a near horizontal position. The high sea chest intake screens will be located in a near vertical plane along the side of the hull. Intake screens will be slotted screens with 1-inch (2.5 cm) by 12-inch (30.5 cm) slots. The combined total open flow area of the low sea chest intake screens on the starboard side of the vessel will be approximately 33.4 ft^2 (3.1 m^2). The combined total open flow area of the high sea chest intake screens on the port side of the vessel will also be approximately 33.4 ft^2 (3.1 m^2).

During normal operations, seawater will be withdrawn from either the high or the low sea chests. There is a preference for use of the low sea chest at the Port. Based on the assumption that plankton are more abundant closer to the water surface, withdrawing seawater from lower in the water column would reduce potential entrainment impacts. At the design withdrawal rate, the intake velocity at a sea chest screen will be approximately 0.1 ft/sec (2.7 cm/s) and in no case (except when fire pumps are turned on) will the intake velocity exceed 0.5 ft/sec (15 cm/s).

In addition to ballast water intake, a dedicated support vessel (SV) will be on call to assist with various Port operations, including onsite security surveillance when LNGRVs are present at the Port, performance of weekly inspections of surface components of the Port facility, transportation of personnel and stores, and provision of towing services (as needed). The SV will also intake an average annual water volume of as much as 1,756,380 m^3 for cooling water and other purposes. This brings the operational water intake to an estimated total of 4,419,420 m^3/yr.

3.2.1 Emergency/Maintenance

The ship will also be equipped with an emergency fire pump sea chest and associated intake screen, located on the starboard side of the vessel. The intake screen that will supply water to the emergency fire pump sea chest will be similar to the screens serving the high and low sea chests (i.e., slotted screen with 1-inch (2.5 cm) by 12-inch (30.5 cm) slots), will be centered at approximately 32 feet (10 m) below the half-cargo waterline, and will have an open area of approximately 2.2 ft^2 (0.2 m^2).

To estimate total seawater intake/discharge over the life of the Project, it was assumed that maintenance activities will occur at 5 year intervals; however, the actual frequency of these “as needed” activities is not certain. The total annual average water use during emergency/maintenance is estimated to be 86,688 m^3/yr for a total combined operation and emergency/maintenance water use of 4,506,108 m^3/yr.

3.2.2 Decommissioning

Decommissioning activities will involve disconnection and in-place abandonment of the Mainline and Laterals and recovery of the STL buoys, PLEMs, flexible risers and control umbilicals. The dive support vessel, tugs and heavy lift vessels used during decommissioning will be similar to those used during project construction. The total annual average water use during decommissioning is estimated to be 494,653 m^3/yr.

4. Ichthyoplankton Assessment Model

Potential entrainment losses are evaluated using an ichthyoplankton assessment methodology (Age-1 equivalent model) for evaluating entrainment impacts of deepwater ports jointly developed by

NOAA/USCG (USCG and MARAD 2004, 2005a, 2005b). The Age-1 equivalent model is a method for expressing impingement and entrainment losses as an equivalent number of individuals at Age-1 (or any other age of relevance). The model provides a means of converting losses of fish eggs and larvae into units of individual fish and provides a standard metric for comparing losses among species, years, and regions. The model requires life-stage specific impingement and entrainment counts and life-stage specific mortality rates from the stage of impingement or entrainment to the life stage of equivalence. It assumes that all pelagic eggs and larvae in the intake water are entrained and suffer mortality.

Age-1 equivalents are calculated as:

$$AE_{1L} = N_L \times S_{L,1}$$

The numbers of Age-1 equivalents lost due to entrainment were calculated by multiplying the number entrained (N_L) by the survival rate from the entrained stage to 1 year of age (S_{L1}). For larvae, survival to age 1 (S_{L1}) is calculated as:

$$S_{L1} = 2\, S^*_L\, e^{-\ln(1+S_L)}\, S_j$$

where SL and Sj are the survival rates for larvae and juveniles, respectively. S_L is adjusted (S^*_L) to account for the fact that the individual fish were entrained at various times within the stage ($S^*_L = 2S_L e^{-\log(1+S_L)}$).

The equations are based on fisheries models typically used for entrainment and impingement impact evaluations, which are further described in the NOAA/USCG jointly-developed ichthyoplankton methodology, (Electric Power Research Institute [EPRI] 2004), and other sources. Life history parameters were compiled from the literature and obtained from EPA (2002).

5. Ichthyoplankton Density

Potential entrainment losses due to construction and operational intakes were estimated using egg and larval density estimates from MARMAP/ECOMON long-term fish monitoring projects (NMFS 2013). Plankton samples were collected during these surveys using a 61-cm bongo net fished from the surface to within 5 meters of the bottom or to a depth of 200 meters. Mesh size of the nets was 505 µm during the early surveys from 1977 to 1987 and 333 µm in later surveys. Surveys were conducted on the continental shelf from Cape Hatteras, North Carolina to Cape Sable, Nova Scotia. For this analysis only stations located within 5 miles of the mainline or port were included (Figures 1 through 4).

Data for taxa that composed more than 1% of eggs or larvae collected at the selected stations and total egg and larvae abundance at those stations were obtained from NOAA (Hare 2012). Abundance data were obtained as the number under 10 m^2 sea surface area and converted to number per 100 m^3 of volume using depth data collected during the surveys. This method assumes a uniform distribution of eggs and larvae throughout the water column, and may overestimate or underestimate abundance based on the depth preference of each species. Average annual density estimates for these taxa are included in Table 3 for eggs along the mainline, Table 4 for larvae along the mainline, Table 5 for eggs at the port and Table 6 for larvae at the port.

Data from 1977 to 2008 were used to estimate abundance. Egg data were available from 1977 to 1987, and larvae data were available from 1977 to 2008. Earlier data (1977-1987) were collected during most months and later data were collected approximately bi-monthly. Because the density of eggs and larvae is variable, the longer dataset may provide a better estimate of average density by taking into account more of the inter-annual variability. Data from the vicinity of the project site were used to provide local estimates of density.

Figure 1 – MARMAP/ECOMON Stations Within 5 Miles of the Mainline Selected to Estimate Egg Density

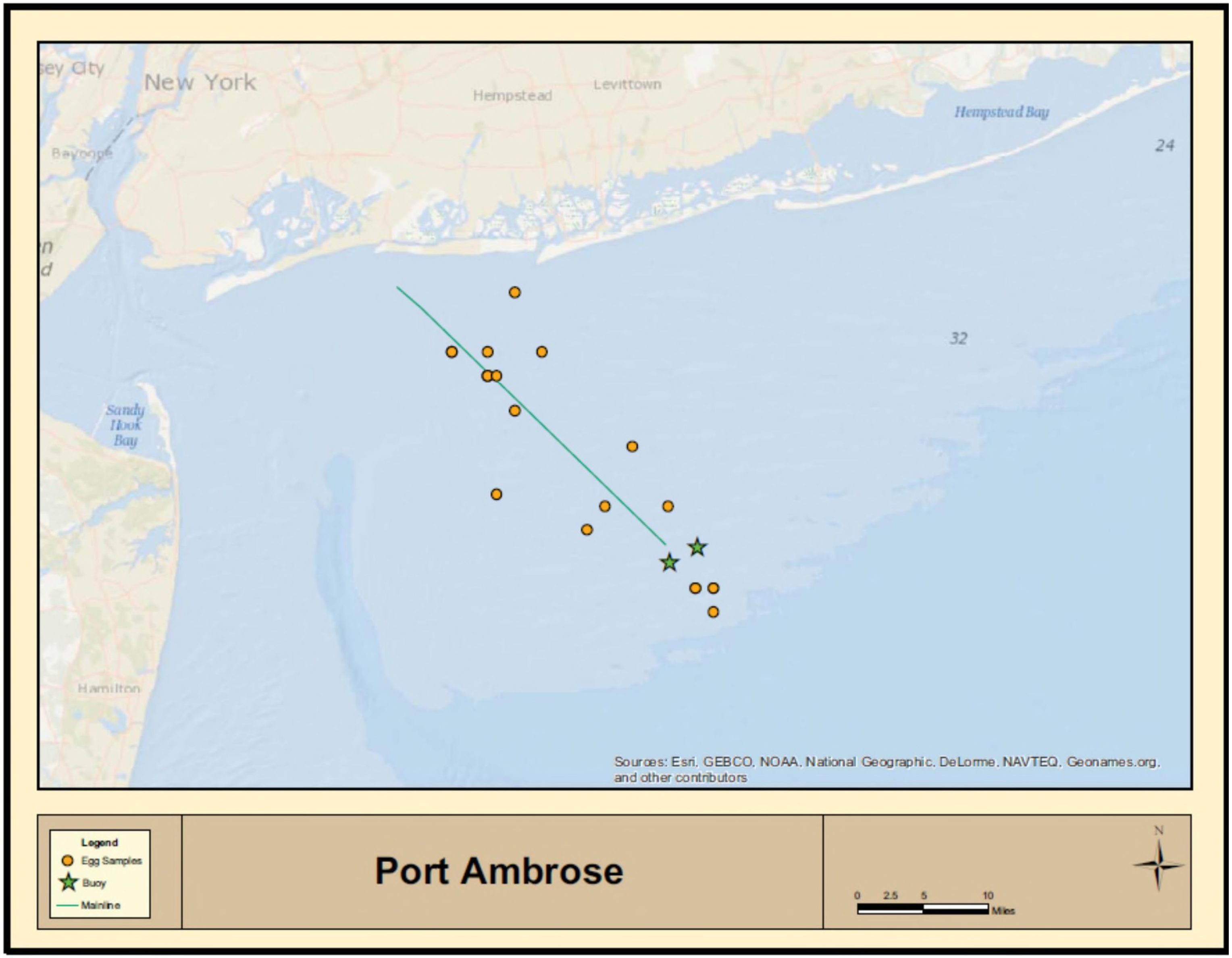

Figure 2 – Selected MARMAP/ECOMON Stations Within 5 miles of the Mainline Selected to Estimate Larvae Density

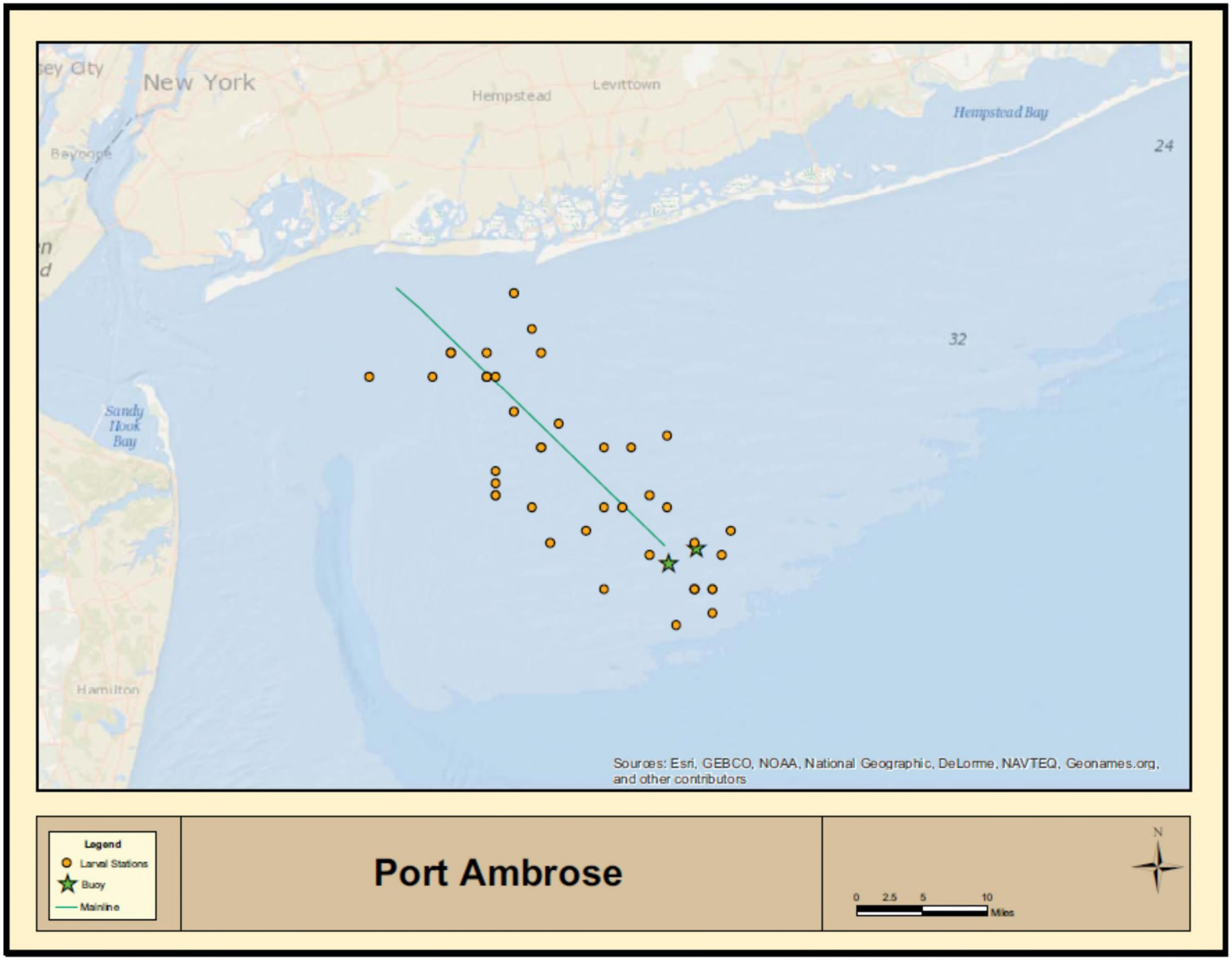

Figure 3 – Selected MARMAP/ECOMON Stations Within 5 miles of the Port Selected to Estimate Egg Density

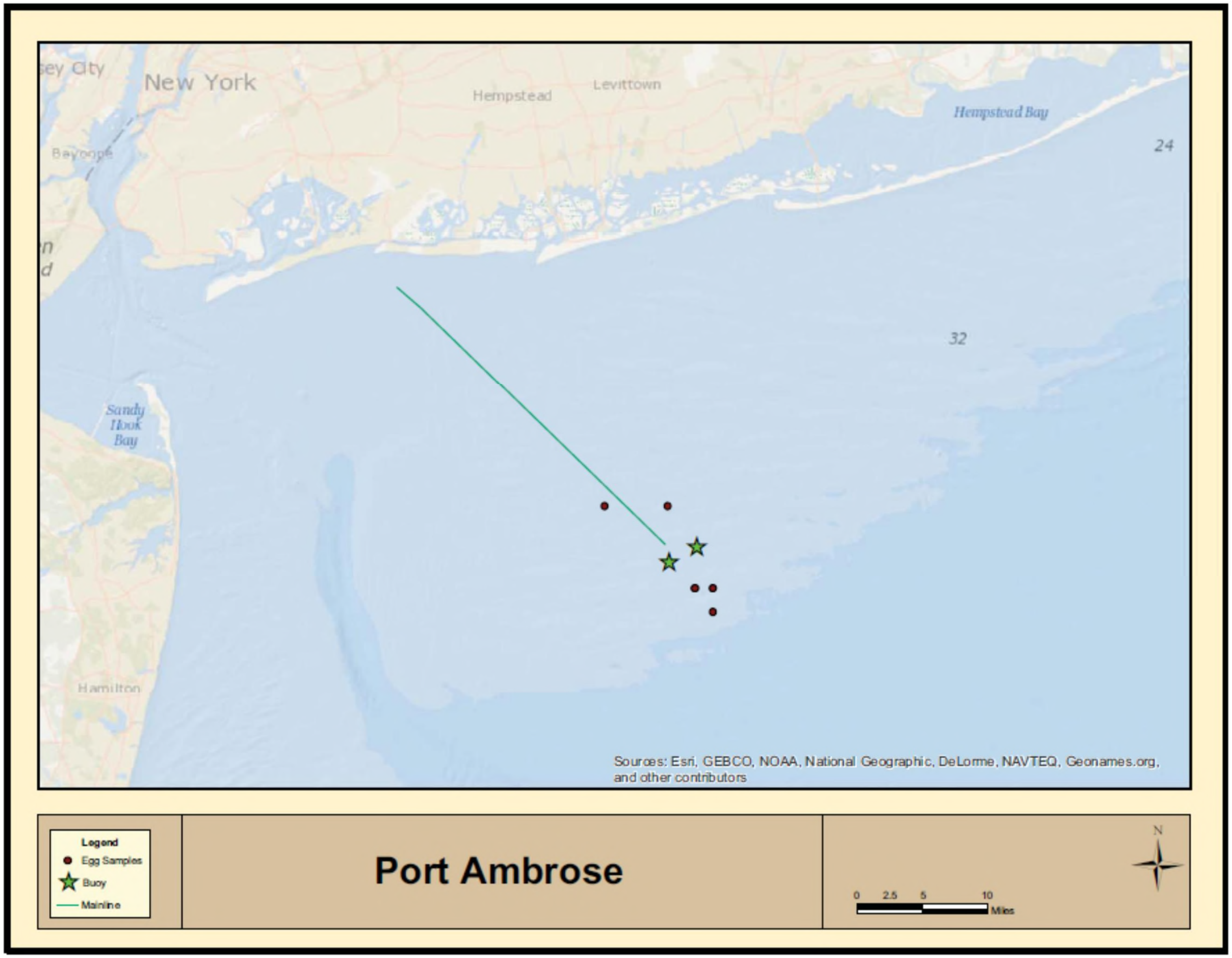

Figure 4 – Selected MARMAP/ECOMON Stations Within 5 miles of the Port with Larvae Data Selected to Estimate Larvae Density

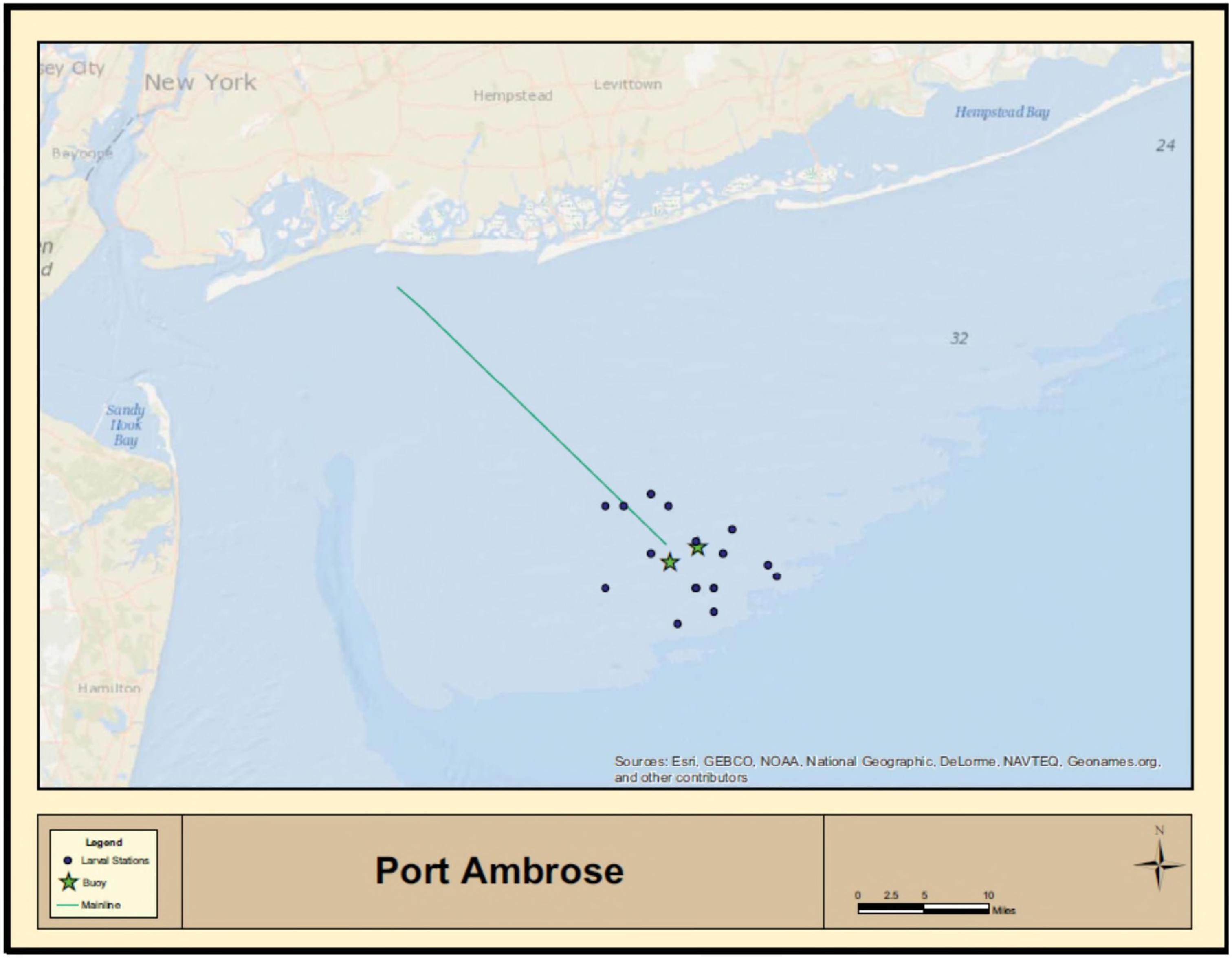

Table 3 – Estimated Annual Average Density of Eggs Along the Mainline Using the MARMAP/ECOMON Data

Taxa	Average Density[1] (#/100m^3)
Unknown eggs	95.15
Anchovy *(Engraulidae sp.)*	9.40
Physcid hakes (red hake) (*Urophycis)*	16.23
Spotted codling (hake) *(Urophycis regia)*	
Fourbeard rockling *(Enchelyopus cimbrius)*	
Silver hake *(Merluccius bilinearis)*	
Bluefish *(Pomatomus saltatris)*	0.71
Atlantic croaker *(Micropogonias undulates)*	
Cunner *(Tautogolabrus adspersus)*	4.82
Atlantic mackerel *(Scomber scombrus)*	304.34
Butterfish *(Peprilus triacanthus)*	
Searobin *(Prionotus sp.)*	
Sand lance *(Ammodytes sp.)*	
Lefteye flounders *(Bothidae sp.)*	
Gulfstream flounder *(Citharichthys arctifrons)*	
Smallmouth flounder *(Etropus microstomus)*	
Fourspot flounder *(Hippoglossina oblonga)*	30.89
Summer flounder *(Paralicthys dentatus)*	
Yellowtail flounder *(Limanda ferruginea)*	41.51
Windowpane flounder *(Scophthalmus aquosus)*	13.00
Flounder sp *(Citharichthys)*	4.23
Total Eggs	525.30

[1]Blanks indicate that these species were not present in the catch data

Table 4 – Estimated Annual Average Density of Larvae Along the Mainline Using the MARMAP/ECOMON Data

Taxa	Average Density[1] (#/100m^3)
Unknown larvae	0.03
Anchovy *(Engraulidae sp.)*	1.34
Physcid hakes (red hake) (*Urophycis)*	5.11
Spotted codling (hake) *(Urophycis regia)*	0.48
Fourbeard rockling *(Enchelyopus cimbrius)*	0.57
Silver hake *(Merluccius bilinearis)*	0.05
Bluefish *(Pomatomus saltatris)*	
Atlantic croaker *(Micropogonias undulates)*	20.74
Cunner *(Tautogolabrus adspersus)*	0.06
Atlantic mackerel *(Scomber scombrus)*	3.45
Butterfish *(Peprilus triacanthus)*	0.72
Searobin *(Prionotus sp.)*	6.16
Sand lance *(Ammodytes sp.)*	13.28
Lefteye flounders *(Bothidae sp.)*	0.14
Gulfstream flounder *(Citharichthys arctifrons)*	1.32
Smallmouth flounder *(Etropus microstomus)*	2.14
Fourspot flounder *(Hippoglossina oblonga)*	0.88
Summer flounder *(Paralicthys dentatus)*	0.43
Yellowtail flounder *(Limanda ferruginea)*	1.9
Windowpane flounder *(Scophthalmus aquosus)*	1.17
Flounder sp *(Citharichthys)*	
Total Eggs	74.22
[1]Blanks indicate that these species were not present in the catch data	

Table 5 – Estimated Annual Average Density of Eggs at the Port Using the MARMAP/ECOMON Data

Taxa	Average Density[1] (#/100m^3)
Unknown eggs	35.34
Anchovy *(Engraulidae sp.)*	
Physcid hakes (red hake) (*Urophycis)*	7.86
Spotted codling (hake) *(Urophycis regia)*	
Fourbeard rockling *(Enchelyopus cimbrius)*	
Silver hake *(Merluccius bilinearis)*	
Bluefish *(Pomatomus saltatris)*	2.04
Atlantic croaker *(Micropogonias undulates)*	
Cunner *(Tautogolabrus adspersus)*	
Atlantic mackerel *(Scomber scombrus)*	737.97
Butterfish *(Peprilus triacanthus)*	
Searobin *(Prionotus sp.)*	
Sand lance *(Ammodytes sp.)*	
Lefteye flounders *(Bothidae sp.)*	
Gulfstream flounder *(Citharichthys arctifrons)*	
Smallmouth flounder *(Etropus microstomus)*	
Fourspot flounder *(Hippoglossina oblonga)*	19.22
Summer flounder *(Paralicthys dentatus)*	
Yellowtail flounder *(Limanda ferruginea)*	81.91
Windowpane flounder *(Scophthalmus aquosus)*	0.53
Flounder sp *(Citharichthys)*	4.08
Total Eggs	890.19
[1]Blanks indicate that these species were not present in the catch data	

Table 6 – Estimated Annual Average Density of Larvae at the Port Using the MARMAP/ECOMON Data

Taxa	Average Density[1] (#/100m^3)
Unknown larvae	0.06
Anchovy *(Engraulidae sp.)*	4.36
Physcid hakes (red hake) (*Urophycis)*	5.80
Spotted codling (hake) *(Urophycis regia)*	0.42
Fourbeard rockling *(Enchelyopus cimbrius)*	0.57
Silver hake *(Merluccius bilinearis)*	0.08
Bluefish *(Pomatomus saltatris)*	0.40
Atlantic croaker *(Micropogonias undulates)*	38.02
Cunner *(Tautogolabrus adspersus)*	0.12
Atlantic mackerel *(Scomber scombrus)*	4.25
Butterfish *(Peprilus triacanthus)*	1.13
Searobin *(Prionotus sp.)*	12.76
Sand lance *(Ammodytes sp.)*	22.13
Lefteye flounders *(Bothidae sp.)*	10.21
Gulfstream flounder *(Citharichthys arctifrons)*	20.97
Smallmouth flounder *(Etropus microstomus)*	2.63
Fourspot flounder *(Hippoglossina oblonga)*	7.04
Summer flounder *(Paralicthys dentatus)*	0.60
Yellowtail flounder *(Limanda ferruginea)*	1.24
Windowpane flounder *(Scophthalmus aquosus)*	0.08
Flounder sp *(Citharichthys)*	
Total larvae	166.77
[1]Blanks indicate that these species were not present in the catch data	

Density estimates of eggs and larvae in the vicinity of the mainline were derived from sampling data at stations located within 5 miles of the mainline. These data were used to evaluate potential entrainment during the construction and decommissioning phases of the project. To evaluate entrainment during the operations phase of the project, density estimates of eggs and larvae in the vicinity of the port were also derived from sampling data at stations located within 5 miles of the port. There is some overlap in the datasets between the port and mainline as the mainline terminates at the port. All available MARMAP/ECOMON data within the target area were included. These datasets included 20 sampling events for mainline eggs, 42 sampling events for mainline larvae, 7 sampling events for port eggs and 18 sampling events for port larvae.

Density data averaged by month, and the monthly densities are included in Table 7 for eggs and Table 8 for larvae along the mainline. Density data averaged by month, and the monthly densities are included in Table 9 for eggs and Table 10 for larvae at the port. Egg and larvae annual density estimates were made by taking the average of each individual sampling event within 5 miles of the mainline and 5 miles of the port for each species and for total eggs and larvae.

Table 7 – Monthly Density Estimates (#/100 m^3) for Eggs Along the Mainline

		Flounder sp	bay anchovy	physcid hakes (red hake)	silver hake	bluefish	cunner	Atlantic mackerel	fourspot flounder	yellowtail flounder	windowpane flounder	
Month	Unknown	*Citharichthys/Etropus*	*Anchoa mitchilli*	*Urophycis*	*Merluccius bilinearis*	*Pomatomus saltatrix*	*Tautogolabrus adspersus*	*Scomber scombrus*	*Hippoglossina oblonga*	*Limanda ferruginea*	*Scophthalmus aquosus*	Total
4								164.3324		101.9034	1.9612	269.1291
5	9.7714							1645.1507		38.9848		1693.9069
6	936.4695							0.4861				936.9556
7			188.0667	207.7000			94.0333		466.0333		88.8667	1096.3667
8		38.0710		28.6559		7.1355	1.1333		70.6774		1.1333	163.8065
9		2.3872		3.0391					2.1455		13.8551	22.4301
10	0.3280	0.6560		25.2003					1.9680		56.7423	87.5648

Table 8 – Monthly Density Estimates (#/100 m^3) for Larvae Along the Mainline

		anchovies	physcid hakes (red hake)	spotted codling (hake)	Fourbeard rockling	silver hake	bluefish	atlantic croaker	cunner	Atlantic mackerel	butterfish	searobin	sand lance	lefteye flounders	gulfstream flounder	smallmouth flounder	fourspot flounder	summer flounder	yellowtail flounder	windowpane flounder	flounder sp	
Month	Unidentified larvae	*Engraulidae*	*Urophycis*	*Urophycis regia*	*Enchelyopus cimbrius*	*Merluccius bilinearis*	*Pomatomus saltatrix*	*Micropogonias undulatus*	*Tautogolabru s adspersus*	*Scomber scombrus*	*Peprilus triacanthus*	*Prionotus*	*Ammodytes*	*Bothidae*	*Citharichthys arctifrons*	*Etropus microstomus*	*Hippoglossina oblonga*	*Paralichthys dentatus*	*Limanda ferruginea*	*Scophthalmus aquosus*	*Citharichthys*	Total
1													1.1083									6.2343
2																						
3													4.0034									6.5502
4													45.1046						2.8912			53.6305
5					3.6923					23.7032			27.0899						8.4006	5.5227		75.8462
6					0.7339	0.4861				9.5387									4.4032			17.3635
7		17.1368									1.1421						4.5684			1.1421		27.4158
8									1.0643		1.0524	2.1286			0.5321	1.5905	3.7250					12.7476
9	0.1287	2.9553	18.3119	1.9878	0.3214			85.5469			2.5535	24.8698		0.3750	5.3216	7.5715	1.7302	1.1563		0.1287		189.5698
10			10.3853			0.3905								0.7810		3.5143	1.5619	1.4043		5.1516		60.1253
11		3.3333	1.3333															2.0000		4.0000		14.0000

Table 9 – Monthly Density Estimates (#/100 m^3) for Eggs at the Port

		Flounder sp	bay anchovy	physcid hakes (red hake)	silver hake	bluefish	cunner	Atlantic mackerel	fourspot flounder	yellowtail flounder	windowpane flounder	
Month	Unknown	*Citharichthys/Etropus*	*Anchoa mitchilli*	*Urophycis*	*Merluccius bilinearis*	*Pomatomus saltatrix*	*Tautogolabrus adspersus*	*Scomber scombrus*	*Hippoglossina oblonga*	*Limanda ferruginea*	*Scophthalmus aquosus*	Total
4								92.2922		152.1341	1.2429	247.8441
5	14.6571							2444.4629		58.4771		2517.5971
6	220.1613											220.1613
8		28.5419		55.0452		14.2710			134.5548			232.4129

Table 10 – Monthly Density Estimates (#/100 m^3) for Larvae at the Port

		anchovies	physcid hakes (red hake)	spotted codling (hake)	Fourbeard rockling	silver hake	bluefish	atlantic croaker	cunner	Atlantic mackerel	butterfish	searobin	sand lance	lefteye flounders	gulfstream flounder	smallmouth flounder	fourspot flounder	summer flounder	yellowtail flounder	windowpane flounder	flounder sp	
Month	Unidentified larvae	*Engraulidae*	*Urophycis*	*Urophycis regia*	*Enchelyopus cimbrius*	*Merluccius bilinearis*	*Pomatomus saltatrix*	*Micropogonias undulatus*	*Tautogolabrus adspersus*	*Scomber scombrus*	*Peprilus triacanthus*	*Prionotus*	*Ammodytes*	*Bothidae*	*Citharichthys arctifrons*	*Etropus microstomus*	*Hippoglossina oblonga*	*Paralichthys dentatus*	*Limanda ferruginea*	*Scophthalmus aquosus*	*Citharichthys*	Total
1													64.2593									64.2593
2																						0.5490
3													51.6970						1.3096			55.7296
4													42.9098						1.7387			49.2887
5					2.0048					28.6790			51.0048						2.8532			95.6613
6					1.4677					19.0774									8.8065			33.7548
8		18.2716	2.9664				2.4074		0.7095		0.6420	9.2413		7.5185	14.5800	10.1540	16.9278			0.1605		141.5782
9	0.3431	7.8807	31.8606	2.5093	1.5978	0.4938		228.1250			6.1265	67.3071		53.7284	111.2165	5.5991	25.3336	3.5772		0.3431		675.5822

6. Model Inputs and Results for Taxa of Concern

The MARMAP/ECOMON data collected within 5 miles of the project site were selected as being most representative of the project area. This is in comparison to the previous version of this report (Volume II, Topic Report 4, Appendix D Ichthyoplankton Entrainment Assessment, September 2012) that utilized an approximate 50-mile radius for sample locations. The data in this report covers a range of years and months and has the advantage of having multiple survey events in the specific project area. However, these data do have some limitations. For example, eggs and larvae can be difficult to differentiate to species level. As a result, individuals that may have been misidentified and/or not identified to species level may not be included in the species-specific density estimates. Conversely, species misidentified may have been included in the density estimates for the wrong species.

These data limitations are compounded by the fact that data regarding ichthyoplankton abundance and distribution are themselves highly variable or patchy. This patchiness derives from the natural variability of environmental influences such as water temperature, hydrographic features, spawning events, and migration patterns. Additionally, the natural mortality of fish is also highly variable and depends on factors such as predation, starvation, weather, and location. Natural mortality varies among species and is greatest during early life-history stages (EPA 2002). Natural mortality can be as high as 96 percent for larvae and 99 percent for eggs (Houde 1987), and only a small percentage of newly hatched eggs or larvae typically survive to adulthood.

Entrainment impacts from construction are calculated by multiplying the ichthyoplankton egg and larvae densities along the mainline by the expected water withdrawal during the construction phase. Estimation of annual entrainment during facility operation involves multiplication of the ichthyoplankton egg and larvae densities at the port by the sum of the expected annual operational withdrawal of the LNGRV and expected annual emergency/maintenance water withdrawal. Estimation of annual larval entrainment during decommissioning is calculated by multiplication of the ichthyoplankton egg and larvae densities by the expected water withdrawal during decommissioning. Estimates of entrainment during construction, operation/emergency/maintenance and decommissioning are shown in Table 11.

Life history data (stage specific mortality) for all species were obtained from Case Studies included in EPA (2002) and used to determine the Age-1 equivalents (Table 12). The estimated number of Age-1 equivalents that would be entrained during construction of the facility is shown in Table 13. The estimated number of Age-1 equivalents that would be entrained annually at the facility due to operations and emergency/maintenance water use is shown in Table 14. The estimated number of Age-1 equivalents that would be entrained annually during decommissioning is shown in Table 15.

Table 11 – Entrainment Estimates Derived from Annual Average Egg and Larvae Densities (number/yr)

	Entrainment During Construction		Annual Entrainment During Operation, Emergency and Maintenance		Annual Entrainment During Decommissioning	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Unknown larvae	8,051,682	2,640	1,605,948	2,577	470,640	154
Anchovy *(Engraulidae sp.)*	795,757	113,121		196,409	46,514	6,612
Physcid hakes (red hake) (*Urophycis)*	1,373,166	432,354	354,342	261,557	80,265	25,272
Spotted codling (hake) *(Urophycis regia)*		40,780		18,845		2,384
Fourbeard rockling *(Enchelyopus cimbrius)*		48,231		25,712		2,819
Silver hake *(Merluccius bilinearis)*		4,496		3,709		263
Bluefish *(Pomatomus saltatris)*	60,384		91,866	18,080	3,530	
Atlantic croaker *(Micropogonias undulates)*		1,755,006		1,713,260		102,584
Cunner *(Tautogolabrus adspersus)*	407,469	5,458		5,329	23,818	319
Atlantic mackerel *(Scomber scombrus)*	25,754,555	292,059	33,253,804	191,348	1,505,414	17,072
Butterfish *(Peprilus triacanthus)*		60,712		50,833		3,549
Searobin *(Prionotus sp.)*		521,124		574,892		30,461
Sand lance *(Ammodytes sp.)*		1,124,021		997,333		65,702
Lefteye flounders *(Bothidae sp.)*		11,699		459,975		684
Gulfstream flounder *(Citharichthys arctifrons)*		111,903		944,755		6,541
Smallmouth flounder *(Etropus microstomus)*		181,511		118,309		10,610

	Entrainment During Construction		Annual Entrainment During Operation, Emergency and Maintenance		Annual Entrainment During Decommissioning	
	Eggs	**Larvae**	**Eggs**	**Larvae**	**Eggs**	**Larvae**
Fourspot flounder *(Hippoglossina oblonga)*	2,613,899	74,326	866,169	317,391	152,789	4,345
Summer flounder *(Paralicthys dentatus)*		36,052		26,865		2,107
Yellowtail flounder *(Limanda ferruginea)*	3,513,113	160,652	3,690,867	55,946	205,350	9,390
Windowpane flounder *(Scophthalmus aquosus)*	1,099,752	98,897	24,002	3,782	64,283	5,781
Flounder sp *(Citharichthys)*	358,029		183,733		20,928	
Total	44,027,806	5,075,044	40,070,732	5,986,906	2,573,528	296,648

[1]Blanks indicate that these species were not present in the catch data

Table 12 – Life History Parameters for Potentially Entrained Species

Species	Natural Mortality (per stage)			Original Source[1]
	Egg	Larvae	Juvenile	
Anchovy *(Engraulidae sp.)*	1.1	7.19	2.09	Froese and Pauly 2003, PG&E National Energy Group 2001
Physcid hakes (red hake) (*Urophycis*)	1.22	6.7	4.83	North Atlantic 316(b)
Spotted codling (hake) *(Urophycis regia)*	1.22	6.7	4.83	North Atlantic 316(b)
Fourbeard rockling *(Enchelyopus cimbrius)*	2.3	4.25	0.916	Deree 1999, Froese and Pauly 2001, 2003; NMFS 2003a
Silver hake *(Merluccius bilinearis)*	1.43	6.62	4.58	PG&E National Energy Group 2001
Bluefish *(Pomatomus saltatris)*	1.35	8.24	5.07	Seabrook and Pilgrim 316(b)
Atlantic croaker *(Micropogonias undulates)*	0.498	2.84	3.39	Assumed same as weakfish North Atlantic 316 (b)
Cunner *(Tautogolabrus adspersus)*	3.49	2.9	2.9	Able and Fahay 1998, Entergy Nuclear Generation Company 2000, Scott and Scott 1988 and Serchuk and Cole 1974
Atlantic mackerel *(Scomber scombrus)*	2.39	5.3	5.3	North Atlantic 316(b)
Butterfish *(Peprilus triacanthus)*	2.3	6.64	0.916	North Atlantic 316(b)
Searobin *(Prionotus sp.)*	2.3	3.66	0.916	Entergy Nuclear Generation Company 2000, Froese and Pauly 2001, 2003; Virginia Tech 1998
Sand lance *(Ammodytes sp.)*	1.41	2.97	2.9	Froese and Pauly 2003, PG&E National Energy Group 2001
Lefteye flounders *(Bothidae sp.)*	1.41	6.99	2.98	Assumed same as summer flounder and windowpane
Gulfstream flounder *(Citharichthys arctifrons)*	1.41	6.99	2.98	Assumed same as summer flounder and windowpane
Smallmouth flounder *(Etropus microstomus)*	1.41	6.99	2.98	Assumed same as summer flounder and windowpane
Fourspot flounder *(Hippoglossina oblonga)*	1.41	6.99	2.98	Assumed same as summer flounder and windowpane
Summer flounder *(Paralicthys dentatus)*	1.41	6.99	2.98	North Atlantic 316(b)

Species	Natural Mortality (per stage)			Original Source[1]
	Egg	Larvae	Juvenile	
Yellowtail flounder *(Limanda ferruginea)*	1.41	6.99	2.98	Assumed same as summer flounder and windowpane
Windowpane flounder *(Scophthalmus aquosus)*	1.41	6.99	2.98	Froese and Pauly 2003, PG&E National Energy Group 2001
Flounder sp *(Citharichthys)*	1.41	6.99	2.98	Assumed same as summer flounder and windowpane

[1]All life history parameters were obtained from the summary of case studies found in EPA (2002). EPA's (2002) original sources as cited in this reference are listed in this table's column.

Table 13 – Annual Age-1 Equivalents for Eggs and Larvae Entrained During Construction of the Facility

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Unknown			8,051,682	2,640			
Anchovy *(Engraulidae sp.)*	4.6587E-05	0.000186402	795,757	113,121	37.1	21.1	58.2
Physcid hakes (red hake) (*Urophycis)*	4.48155E-06	1.96372E-05	1,373,166	432,354	6.2	8.5	14.6
Spotted codling (hake) *(Urophycis regia)*	4.48155E-06	1.96372E-05		40,780		0.8	0.8
Fourbeard rockling *(Enchelyopus cimbrius)*	0.001040142	0.011254173		48,231		542.8	542.8
Silver hake *(Merluccius bilinearis)*	5.28094E-06	2.7312E-05		4,496		0.1	0.1
Bluefish *(Pomatomus saltatris)*	6.42846E-07	3.12175E-06	60,384		0.0		0.0
Atlantic croaker *(Micropogonias undulates)*	0.001488948	0.003721474		1,755,006		6531.2	6531.2
Cunner *(Tautogolabrus adspersus)*	0.00017922	0.005739314	407,469	5,458	73.0	31.3	104.4
Atlantic mackerel *(Scomber scombrus)*	4.18282E-06	4.95845E-05	25,754,555	292,059	107.7	14.5	122.2
Butterfish *(Peprilus triacanthus)*	9.53079E-05	0.001044561		60,712		63.4	63.4
Searobin *(Prionotus sp.)*	0.001876404	0.020075405		521,124		10,461.8	10,461.8
Sand lance *(Ammodytes sp.)*	0.001107888	0.005370236		1,124,021		6,036.3	6,036.3
Lefteye flounders *(Bothidae sp.)*	1.83607E-05	9.3479E-05		11,699		1.1	1.1

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Gulfstream flounder *(Citharichthys arctifrons)*	1.83607E-05	9.3479E-05		111,903		10.5	10.5
Smallmouth flounder *(Etropus microstomus)*	1.83607E-05	9.3479E-05		181,511		17.0	17.0
Fourspot flounder *(Hippoglossina oblonga)*	1.83607E-05	9.3479E-05	2,613,899	74,326	48.0	6.9	54.9
Summer flounder *(Paralicthys dentatus)*	1.83607E-05	9.3479E-05		36,052		3.4	3.4
Yellowtail flounder *(Limanda ferruginea)*	1.83607E-05	9.3479E-05	3,513,113	160,652	64.5	15.0	79.5
Windowpane flounder *(Scophthalmus aquosus)*	1.83607E-05	9.3479E-05	1,099,752	98,897	20.2	9.2	29.4
Flounder sp *(Citharichthys)*	1.83607E-05	9.3479E-05	358,029		6.6		6.6
Total (excluding unknown)							24,138.2

Table 14 – Annual Age-1 Equivalents for Eggs and Larvae Entrained Annually During Operation, Emergency/Maintenance at the Port

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Unknown			1,605,948	2,577			
Anchovy *(Engraulidae sp.)*	4.6587E-05	0.000186402		196,409		36.6	36.6
Physcid hakes (red hake) (*Urophycis)*	4.48155E-06	1.96372E-05	354,342	261,557	1.6	5.1	6.7
Spotted codling (hake) *(Urophycis regia)*	4.48155E-06	1.96372E-05		18,845		0.4	0.4
Fourbeard rockling *(Enchelyopus cimbrius)*	0.001040142	0.011254173		25,712		289.4	289.4
Silver hake *(Merluccius bilinearis)*	5.28094E-06	2.7312E-05		3,709		0.1	0.1
Bluefish *(Pomatomus saltatris)*	6.42846E-07	3.12175E-06	91,866	18,080	0.1	0.1	0.1
Atlantic croaker *(Micropogonias undulates)*	0.001488948	0.003721474		1,713,260		6,375.9	6,375.9
Cunner *(Tautogolabrus adspersus)*	0.00017922	0.005739314		5,329		30.6	30.6
Atlantic mackerel *(Scomber scombrus)*	4.18282E-06	4.95845E-05	33,253,804	191,348	139.1	9.5	148.6
Butterfish *(Peprilus triacanthus)*	9.53079E-05	0.001044561		50,833		53.1	53.1
Searobin *(Prionotus sp.)*	0.001876404	0.020075405		574,892		11,541.2	11,541.2
Sand lance *(Ammodytes sp.)*	0.001107888	0.005370236		997,333		5,355.9	5,355.9
Lefteye flounders *(Bothidae sp.)*	1.83607E-05	9.3479E-05		459,975		43.0	43.0

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Gulfstream flounder *(Citharichthys arctifrons)*	1.83607E-05	9.3479E-05		944,755		88.3	88.3
Smallmouth flounder *(Etropus microstomus)*	1.83607E-05	9.3479E-05		118,309		11.1	11.1
Fourspot flounder *(Hippoglossina oblonga)*	1.83607E-05	9.3479E-05	866,169	317,391	15.9	29.7	45.6
Summer flounder *(Paralicthys dentatus)*	1.83607E-05	9.3479E-05		26,865		2.5	2.5
Yellowtail flounder *(Limanda ferruginea)*	1.83607E-05	9.3479E-05	3,690,867	55,946	67.8	5.2	73.0
Windowpane flounder *(Scophthalmus aquosus)*	1.83607E-05	9.3479E-05	24,002	3,782	0.4	0.4	0.8
Flounder sp *(Citharichthys)*	1.83607E-05	9.3479E-05	183,733		3.4		3.4
Total (excluding unknown)							24,106.1

Table 15 – Annual Age-1 Equivalents for Eggs and Larvae Entrained During Decommissioning of the Facility

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Unknown			470,640	154			
Anchovy *(Engraulidae sp.)*	4.6587E-05	0.000186402	46,514	6,612	2.2	1.2	3.4
Physcid hakes (red hake) (*Urophycis)*	4.48155E-06	1.96372E-05	80,265	25,272	0.4	0.5	0.9
Spotted codling (hake) *(Urophycis regia)*	4.48155E-06	1.96372E-05		2,384		0.0	0.0
Fourbeard rockling *(Enchelyopus cimbrius)*	0.001040142	0.011254173		2,819		31.7	31.7
Silver hake *(Merluccius bilinearis)*	5.28094E-06	2.7312E-05		263		0.0	0.0
Bluefish *(Pomatomus saltatris)*	6.42846E-07	3.12175E-06	3,530		0.0		0.0
Atlantic croaker *(Micropogonias undulates)*	0.001488948	0.003721474		102,584		381.8	381.8
Cunner *(Tautogolabrus adspersus)*	0.00017922	0.005739314	23,818	319	4.3	1.8	6.1
Atlantic mackerel *(Scomber scombrus)*	4.18282E-06	4.95845E-05	1,505,414	17,072	6.3	0.8	7.1
Butterfish *(Peprilus triacanthus)*	9.53079E-05	0.001044561		3,549		3.7	3.7
Searobin *(Prionotus sp.)*	0.001876404	0.020075405		30,461		611.5	611.5
Sand lance *(Ammodytes sp.)*	0.001107888	0.005370236		65,702		352.8	352.8
Lefteye flounders *(Bothidae sp.)*	1.83607E-05	9.3479E-05		684		0.1	0.1
Gulfstream flounder *(Citharichthys arctifrons)*	1.83607E-05	9.3479E-05		6541		0.6	0.6

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Smallmouth flounder *(Etropus microstomus)*	1.83607E-05	9.3479E-05		10,610		1.0	1.0
Fourspot flounder *(Hippoglossina oblonga)*	1.83607E-05	9.3479E-05	152,789	4,345	2.8	0.4	3.2
Summer flounder *(Paralicthys dentatus)*	1.83607E-05	9.3479E-05		2,107		0.2	0.2
Yellowtail flounder *(Limanda ferruginea)*	1.83607E-05	9.3479E-05	205,350	9,390	3.8	0.9	4.6
Windowpane flounder *(Scophthalmus aquosus)*	1.83607E-05	9.3479E-05	64,283	5,781	1.2	0.5	1.7
Flounder sp *(Citharichthys)*	1.83607E-05	9.3479E-05	20,928		0.4		0.4
Total (excluding unknown)							1,410.9

7. Forgone Fishery Yield

Foregone fishery yield is a measure of the amount of fish or shellfish (in pounds) that is not harvested because the fish are lost to impingement and entrainment. The model involves multiplying age-specific harvest rates by age-specific weights to calculate age-specific expected yields (in pounds). The model assumes that the yield from a cohort of fish is proportional to the number recruited; the annual growth, natural mortality and fishing mortality rates are known and constant; and natural mortality includes mortality due to impingement and entrainment (I&E).

The lifetime expected yield for a cohort of fish is the sum of all age-specific expected yields:

$$Y = \sum \sum N_j * S_{ja} * W_a * (1\text{-}\exp(-Z_a)) * (F_a / Z_a)$$

Where:

Y = forgone yield (in pounds) due to I & E losses

N_j = number of individuals lost from stage j

S_{ja} = cumulative survival from stage j to stage a

W_a = average weight (pounds) of fish at stage a

F_a = instantaneous annual fishing mortality rate for fish of stage a

Z_a = instantaneous annual total mortality rate for fish of stage a

Forgone fishery yield for the estimated annual entrainment from operation of the facility was calculated for each of the selected species and is included in Table 11.

Forgone fishery yield for the estimated annual entrainment from construction, operation, emergency water use and maintenance, and decommissioning of the facility was calculated for each of the species potentially entrained and is included in Table 16.

Table 16 – Estimated Annual Forgone Fishery Yield

Species	Construction Annual Forgone Fishery Yield (pounds)	Operation, Emergency and Maintenance Annual Forgone Fishery Yield (pounds)	Decommissioning Annual Forgone Fishery Yield (pounds)
Unknown			
Anchovy (*Engraulidae sp.*)	0.0	0.0	0.0
Physcid hakes (red hake) (*Urophycis*)	4.2	1.9	0.2
Spotted codling (hake) (*Urophycis regia*)	0.2	0.1	0.0
Fourbeard rockling (*Enchelyopus cimbrius*)	0.0	0.0	0.0
Silver hake (*Merluccius bilinearis*)	0.0	0.0	0.0
Bluefish (*Pomatomus saltatris*)	0.1	0.2	0.0

Species	Construction Annual Forgone Fishery Yield (pounds)	Operation, Emergency and Maintenance Annual Forgone Fishery Yield (pounds)	Decommissioning Annual Forgone Fishery Yield (pounds)
Atlantic croaker (*Micropogonias undulates*)	1,333.5	1,301.8	77.9
Cunner (*Tautogolabrus adspersus*)	0.6	0.2	0.0
Atlantic mackerel (*Scomber scombrus*)	18.7	22.7	1.1
Butterfish (*Peprilus triacanthus*)	1.8	1.5	0.1
Searobin (*Prionotus sp.*)	436.0	480.9	25.5
Sand lance (*Ammodytes sp.*)	0.0	0.0	0.0
Lefteye flounders (*Bothidae sp.*)	0.0	0.8	0.0
Gulfstream flounder (*Citharichthys arctifrons*)	0.2	1.7	0.0
Smallmouth flounder (*Etropus microstomus*)	1.1	0.9	0.1
Fourspot flounder (*Hippoglossina oblonga*)	1.1	0.9	0.1
Summer flounder (*Paralicthys dentatus*)	0.1	0.0	0.0
Yellowtail flounder (*Limanda ferruginea*)	1.5	1.4	0.1
Windowpane flounder (*Scophthalmus aquosus*)	0.6	0.0	0.0
Flounder sp (*Citharichthys*)	0.1	0.1	0.0
Total (*excluding unknown*)	1,799.7	1,815.3	105.2

7.1 Value

Commercial and recreational fishing statistics for New York were used to provide a value estimate for fish that may be entrained during construction and operation of the facility. Total annual landings for New York from 2003 to 2012 for commercial fisheries and 2003 to 2012 for recreational fisheries were obtained from the National Marine Fisheries Service (NMFS) Annual Landings data (NMFS 2013) and are used to provide estimated annual landings for each species considered in this analysis. Table 17 includes the average annual commercial and recreational landings data.

Price per pound for commercial fisheries and an estimated value per fish for recreational fisheries are also included in Table 17. Commercial prices were obtained from NMFS landings data, and recreational values were estimated by EPA in a benefits analysis for the proposed Clean Water Act Section 316(b) rule. These data can be used to provide an estimated value for the fish entrained.

Table 17 – Average Annual Landings

Species	Commercial[2] (years of reported data in parentheses)	Recreational[3,4] (years of reported data in parentheses)	Commercial ($ per lb)[1]	Recreational ($ per individual fish)[5]
Unknown				
Anchovy *(Engraulidae sp.)*				$2.91
Physcid hakes (red hake) (*Urophycis)*		31,329 (10)		$2.91
Spotted codling (hake) *(Urophycis regia)*				$2.91
Fourbeard rockling *(Enchelyopus cimbrius)*				$2.91
Silver hake *(Merluccius bilinearis)*				$2.91
Bluefish *(Pomatomus saltatris)*	1,2245,411 (10)	4,359,534 (9)	$0.48	$2.91
Atlantic croaker *(Micropogonias undulates)*	4,668 (10)		$0.75	$2.91
Cunner *(Tautogolabrus adspersus)*	5,237 (10)	1,395 (9)	$3.88	$2.91
Atlantic mackerel *(Scomber scombrus)*	127,677 (10)	11,295 (4)	$0.47	$2.91
Butterfish *(Peprilus triacanthus)*	391,497 (10)		$0.81	$2.91
Searobin *(Prionotus sp.)*	24,880 (9)		$0.21	$2.91
Sand lance *(Ammodytes sp.)*				$2.91
Lefteye flounders *(Bothidae sp.)*				$5.60
Gulfstream flounder *(Citharichthys arctifrons)*				$5.60
Smallmouth flounder *(Etropus microstomus)*				$5.60
Fourspot flounder *(Hippoglossina oblonga)*	14,415 (7)	413 (5)	$0.39	$5.60
Summer flounder *(Paralicthys dentatus)*	1,274,351 (10)	2,562,653 (10)	$2.57	$5.60
Yellowtail flounder *(Limanda ferruginea)*	55,362 (10)		$1.55	$5.60

Species	Commercial[2] (years of reported data in parentheses)	Recreational[3,4] (years of reported data in parentheses)	Commercial ($ per lb)[1]	Recreational ($ per individual fish)[5]
Windowpane flounder *(Scophthalmus aquosus)*	61,884 (10)	152 (10)	$0.57	$5.60
Flounder sp *(Citharichthys)*				$5.60
Total (excluding unknown)				

[1]Blank cells had no catch data reported between 2003 and 2012

[2]Commercial Landings data for NY, average lb/year and $/lb from 2003 to 2012. Source: NOAA Annual Commercial Landings Statistics (NMFS 2013).

[3]Recreational Landings data for NY, average lb/year from 2003 to 2012. Source: NOAA NMFS, Fisheries Statistics (NMFS 2013).

[4]Records without recorded weights were not included.

[5]Recreational Values are from Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule. Winter and summer flounder were estimated in this report and used for all flounders; all other species have the value reported for other saltwater species. (EPA, 2011).

In addition to recreational and commercial value, fish also have indirect and non-use values. Indirect values are generally considered for forage fish and non-use values are the intrinsic value that a resource has in the public opinion. These values are hard to quantify. Due to the limitations and uncertainties involved in calculating indirect and non-use values as well as the fact that most of the species included in this study have recreational and/or commercial value, these values have not been included in this analysis.

The commercial value of the forgone fishery yield calculated for each of the selected species is included in Table 18.

Table 18 – Estimated Annual Forgone Fishery Yield Commercial Value

Species	Construction Annual Forgone Fishery Yield Commercial Value	Operation, Emergency and Maintenance Annual Forgone Fishery Yield Commercial Value	Decommissioning Annual Forgone Fishery Yield Commercial Value
Unknown			
Anchovy (*Engraulidae sp.*)			
Physcid hakes (red hake) (*Urophycis*)			
Spotted codling (hake) (*Urophycis regia*)			
Fourbeard rockling (*Enchelyopus cimbrius*)			
Silver hake (*Merluccius bilinearis*)			
Bluefish (*Pomatomus saltatris*)	$0.03	$0.09	$0.00
Atlantic croaker (*Micropogonias undulates*)	$1,000.78	$976.97	$58.50
Cunner (*Tautogolabrus adspersus*)	$2.25	$0.66	$0.13
Atlantic mackerel (*Scomber scombrus*)	$8.85	$10.76	$0.52
Butterfish (*Peprilus triacanthus*)	$1.48	$1.24	$0.09
Searobin (*Prionotus sp.*)	$89.51	$98.75	$5.23
Sand lance (*Ammodytes sp.*)			
Lefteye flounders (*Bothidae sp.*)			
Gulfstream flounder (*Citharichthys arctifrons*)			
Smallmouth flounder (*Etropus microstomus*)			
Fourspot flounder (*Hippoglossina oblonga*)	$0.42	$0.35	$0.02
Summer flounder (*Paralicthys dentatus*)	$0.17	$0.13	$0.01

Species	Construction Annual Forgone Fishery Yield Commercial Value	Operation, Emergency and Maintenance Annual Forgone Fishery Yield Commercial Value	Decommissioning Annual Forgone Fishery Yield Commercial Value
Yellowtail flounder (*Limanda ferruginea*)	$2.39	$2.20	$0.14
Windowpane flounder (*Scophthalmus aquosus*)	$0.32	$0.01	$0.02
Flounder sp (*Citharichthys*)			
Total (excluding unknown)	$1,106.22	$1,091.16	$64.66

7.2 Uncertainty

The models used in this analysis simplify very complex processes. This inherent simplification can lead to inaccuracies in the final results. Examples of sources of uncertainty in the process include: eggs and larvae are difficult to identify to the species level and therefore, species totals in the MARMAP/ECOMON data may underestimate or overestimate the densities, especially for particularly hard to identify species; only recreational and commercial values are considered, and non-use or indirect values are not included; life history values are considered constant; market values of fish are also assumed constant; landings of commercial and recreational fish are assumed to be within the state where the facility will be located; egg and larval densities are assumed to be constant over space, depth, and time; entrainment survival is assumed to be zero; and all age-1 fish are valued as if they were harvested.

This analysis is intended to be an estimate of entrainment losses of species that may occur at the facility and to provide some quantification of the value of that loss. However, it does provide a reasonably conservative estimate of the magnitude of the loss of fish to entrainment.

7.3 Sensitivity Analysis

Because of the uncertainties described above, especially the variability in ichthyoplankton densities, a sensitivity analysis was used to provide a range of entrainment using the variation in monthly densities of eggs and larvae. Ichthyoplankton densities are variable both spatially and temporally, dependent upon such things as spawning behavior, currents, and weather. The use of minimum and maximum monthly densities can give an estimate of this variability. Because of the limited MARMAP/ECOMON data available within 5 miles of the mainline and port locations, each species potentially entrained was not encountered for at least one month. Therefore the minimum entrainment estimate based on the minimum monthly density for each species is zero. Estimated annual entrainment maximum densities are shown in Table 19.

Table 19 – Entrainment Estimates Based on Maximum Monthly Densities

	Entrainment During Construction		Annual Entrainment During Operation, Emergency and Maintenance		Annual Entrainment During Decommissioning	
	Eggs	Larvae	Eggs	Larvae	Eggs	Larvae
Unknown larvae	79,248,706	10,889	9,920,706	15,462	4,632,272	637
Anchovy *(Engraulidae sp.)*	15,915,136	1,450,205		823,338	930,277	84,768
Physcid hakes (red hake) (*Urophycis*)	17,576,606	1,549,643	2,480,394	1,435,674	1,027,394	90,580
Spotted codling (hake) *(Urophycis regia)*		168,216		113,070		9,833
Fourbeard rockling *(Enchelyopus cimbrius)*		312,462		90,340		18,264
Silver hake *(Merluccius bilinearis)*		41,137		22,252		2,405
Bluefish *(Pomatomus saltatris)*	603,840		643,065	108,480	35,296	
Atlantic croaker *(Micropogonias undulates)*		7,239,402		10,279,559		423,160
Cunner *(Tautogolabrus adspersus)*	7,957,568	90,065		31,972	465,138	5,265
Atlantic mackerel *(Scomber scombrus)*	139,220,827	2,005,879	110,150,136	1,292,308	8,137,783	117,248
Butterfish *(Peprilus triacanthus)*		216,092		276,069		12,631
Searobin *(Prionotus sp.)*		2,104,605		3,032,931		123,019
Sand lance *(Ammodytes sp.)*		3,816,975		2,895,592		223,111
Lefteye flounders *(Bothidae sp.)*		66,088		2,421,060		3,863
Gulfstream flounder *(Citharichthys arctifrons)*		450,341		5,011,537		26,324

	Entrainment During Construction		Annual Entrainment During Operation, Emergency and Maintenance		Annual Entrainment During Decommissioning	
	Eggs	**Larvae**	**Eggs**	**Larvae**	**Eggs**	**Larvae**
Smallmouth flounder *(Etropus microstomus)*		640,737		457,549		37,453
Fourspot flounder *(Hippoglossina oblonga)*	39,438,057	386,602	6,063,186	1,141,561	2,305,247	22,598
Summer flounder *(Paralicthys dentatus)*		169,250		161,191		9,893
Yellowtail flounder *(Limanda ferruginea)*	8,623,573	710,901	6,855,327	396,828	504,068	41,554
Windowpane flounder *(Scophthalmus aquosus)*	7,520,339	467,361	56,004	15,462	439,581	27,318
Flounder sp *(Citharichthys)*	3,221,755		1,286,130		188,319	
Total	319,326,407	21,896,850	137,454,950	30,022,235	18,665,375	1,279,922

[1]Blanks indicate that these species were not present in the catch data.

Comparison of the maximum entrainment densities in Table 19 to the average entrainment densities in Table 11 provides an indication of the range of entrainment losses that may occur. The estimate of total entrainment using maximum densities, a hypothetical worst case scenario, is 8 times greater for eggs and 4 times greater for larvae than the estimate using average densities. However, due to the high rates of mortality associated with these life stages, this still represents a minor impact to the fishery.

8. Summary

The location and operation of the facility are designed to minimize impacts to the aquatic environment. Impingement impacts are not expected to occur as intake velocities will be less than 0.5 foot per second during construction and operation, emergency and maintenance and decommissioning. The offshore location of the buoys where operational intakes will occur reduces the expected entrainment due to lower densities of fish eggs and larvae as compared with a shoreline or near-shore intake.

Estimated entrainment for the construction phase of the facility is 44,027,806 eggs and 5,075,044 larvae of fish. Estimated annual entrainment during operation, emergency and maintenance activities of the facility is 40,070,732 eggs and 5,986,906 larvae. Estimated annual entrainment during decommissioning of the facility is 2,573,528 eggs and 296,648 larvae. This results in a loss of 24,138 Age-1 equivalent fish during construction, 24,106 Age-1 equivalent fish annually during operation, emergency and maintenance and a loss of 1411 Age-1 equivalent fish during decommissioning of the facility. These numbers equate to approximately 3270 pounds of foregone fishery yield with a value of $2,262.04. This equates to a very small percentage (much less than 1%) of the annual commercial and recreational fishery harvest.

To put these numbers into perspective, EPA (2002) estimated that total national losses of Age-1 equivalents due to impingement and entrainment from 554 power plants includes 3.4 billion fish, and that about half of these losses, 1.7 billion fish, occur in the Mid-Atlantic region at 44 power plants included in the analysis. All 44 power facilities withdraw water from an estuary or tidal river where productivity is higher than on the continental shelf.

As an example, the Crown Landing LNG facility estimated annual impingement and entrainment to be 1.1 million Age-1 equivalents of representative important species (FERC, 2005). That facility is located on the Delaware Estuary and assumes a maximum annual withdrawal of 2,055 million gallons. While the Crown Landing facility has withdrawn its application from FERC and will not be constructed as proposed, it is a good example of estimated entrainment impacts from an LNG facility in a more productive estuarine area. The Port Ambrose project will withdraw approximately a quarter as much water and because of its offshore location, entrain far fewer Age-1 equivalent fish.

Entrainment impacts from Port Ambrose are expected to be very minor due to its location in a low-productivity, off-shore area and its relatively limited water withdrawals. Annual entrainment at this facility is estimated to be less than 25,000 Age-1 equivalent fish.

9. References

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APPENDIX A

Intake Volume Estimates

Port Ambrose Project water intakes and discharges are anticipated to occur in association with the project phases/activities listed below and are summarized in the associated tables that follow:

- Table 1 – construction vessel seawater intake/discharge;
- Table 2 – construction phase hydrostatic testing intake/discharge;
- Table 3 – LNGRV/STL buoy commissioning (potential for once-through cooling water intake/discharge);
- Table 4 – operations phase LNGRV and support vessel seawater intake/discharge;
- Table 5 – maintenance & repair and emergency scenario dive support vessel seawater intake/discharge (activities to be performed on an "as needed" basis);
- Table 6 – decommissioning phase vessel seawater intake/discharge (undertaken at the end of project life); and
- Table 7 – Summary.

Seawater intake and discharge rates and volumes from various construction vessels, crew boats, tugs, and other support vessels are included in several of the tables including Table 1, Table 4, Table 5 and Table 6. The discharge rates shown are for "typical" vessels and can vary depending on the specific construction and support vessels available for use at the time of construction, operation, and decommissioning phases.

The main use of seawater for these vessels is as once-through cooling water. Some vessels also use small quantities of water for potable water (after treatment), wash water, fire water and other miscellaneous service water purposes.

As described in the DWP application and presented in Table 2, seawater intake and discharge will also be required in support of construction phase hydrostatic testing of the Mainline pipeline, laterals and various related appurtenances (subsea tie-in, buoy risers, collocated Y assembly, etc.). Approximately 3.5 million gallons of seawater will be used in support of the hydrostatic testing program.

As described in the DWP application and presented in Table 3, it is possible that seawater withdrawal and discharge will be required for cooling purposes during the LNGRV/STL buoy commissioning period (a timeframe of up to 45 days). The estimated average cooling water withdrawal/discharge rate in support of commissioning activities is approximately 5,700 gallons per minute.

Table 4 provides anticipated seawater intake and discharge in support of normal operations at the Port. It is important to note that the only operational discharges at the Port will be the cooling water discharges from the Port's support vessel (tug). There will be no discharges of cooling water, sanitary effluent (black water), hoteling effluent (gray water) or other effluent while the LNGRV is at the Port. The LNGRV will use seawater from its ballast water tanks as a source of cooling water for its engines and auxiliary cooling needs. Sufficient storage will be provided on the vessel to eliminate the need to discharge black water or gray water while at the Port. The LNGRV will withdraw ballast water during regasification to replace the weight of LNG that has been offloaded from the vessel. The estimated support vessel seawater intake/discharge conservatively assumes that a support vessel will be at the Port and operating 365 days per year.

Table 5 provides estimates of vessel seawater intake/discharge that might occur periodically, as needed, in association with maintenance and repair activities and/or in response to emergency scenarios. For the purpose of estimating total seawater intake/discharge over the life of the Project, it will be assumed that these activities will occur at 5 year intervals; however, the actual frequency of these "as needed" activities is not certain.

Table 6 provides estimates of vessel seawater intake/discharge associated with the ultimate decommissioning of the Port at the end of its useful life. Decommissioning activities will involve disconnection and in-place abandonment (including pre-abandonment flooding) of the Mainline and Laterals and recovery of the STL buoys, PLEMs, flexible risers and control umbilicals. Table 6 assumes that the dive support vessel, tugs and heavy lift vessels used during decommissioning will be similar to those used during Project construction.

Table 7 provides a summary of the seawater intake/discharge for all of the activities described in the prior tables. Approximately half of the water withdrawn will be used as ballast water by the LNGRV. The LNGRV is anticipated to have no discharges at the Port, except for the potential cooling water discharge during the LNGRV/STL buoy commissioning period.

Table 1 – Construction Vessel Seawater Intake and Discharge

Activity	Location	Vessel Type	Typical Operation and Duration	Total SW Intake (gpm)	Total SW Disch. (gpm)	CW Intake/ Disch. (gpm)	Total Operation (hrs)	Total SW Intake (MMgal)	Total SW Disch. (MMgal)	Total CW Intake/ Disch. (MMgal)	Approx. Timing
Hot Tap Installation (intake/ discharge based on 2 tugs)	Transco Pipeline	Work barge (anchored) / Tug	24/7 for 36 days	1,765	1,761	1,761	864	91.5	91.3	91.3	Feb/Mar 2015
Pipeline Installation	Mainline route & Port	DP Pipelay Vessel	24/7 for 45 days	8,827	8,805	8,805	1080	572.0	570.6	570.6	Apr/May 2015
Pipe Haul Spread (intake/ discharge based on 3 tugs)		Tug boat escorting barge		2,644	2,642	2,642	1080	171.3	171.2	171.2	Apr/May 2015
Pipeline Lowering and Backfilling	Mainline route	DP Plow Vessel	24/7 for 90 days	4,411	4,403	4,403	2160	571.7	570.6	570.6	May-Jul 2015
Hot Tap Tie-in	Transco Pipeline	DP Dive Support Vessel (DSV)	24/7 for 46 days	1,325	1,321	1,321	1104	87.8	87.5	87.6	Jul-Sep 2015
Collocated Y Install & Tie-in	Port										
PLEM to Lateral Tie-ins	Port										
Crew Boat	Mainline & Port	Crew Boat	12/7 for 6 months	441	440	440	2160	57.1	57.1	57.1	Apr-Oct 2015
DP DWP Installations	Port	Heavy Lift Vessel	24/7 for 26 days	4	0	0	624	0.2	0.0	0.0	Jul 2015
	Port	DP DSV	24/7 for 58 days	1,325	1,321	1,321	1392	110.7	110.3	110.3	Jul/Aug 2015
Flood, Hydrotest, Dewater (intake/ discharge for tugs based on 2 tugs)	Port	Work barge (anchored) / Tug	24/7 for 45 days	1,765	1,761	1,761	1080	114.4	114.1	114.1	Sep/Oct 2015
	Transco Pipeline	DP DSV	24/7 for 45 days	1,325	1,321	1,321	1080	85.9	85.6	85.6	Sep/Oct 2015
Total Construction Vessel Seawater Intake and Discharge								**1,862.6**	**1,858.2**	**1,858.2**	--

Notes:
1. Approximate timing based on construction schedule presented in the September 2012 DWP application.
2. Total seawater (SW) intake rate estimated as cooling water (CW) intake rate plus estimated potable water and miscellaneous service water demand.
3. Heavy Lift Vessel (HLV) assumed to have closed cycle cooling and no CW intake/discharge.

Table 2 – Construction Phase Hydrostatic Testing Seawater Intake and Discharge

Pipeline Segment	Intake/ Discharge Location	Total SW Intake (gals)	Total SW Discharge (gals)	Approx. Timing
Flood subsea tie-in: 30-inch header, 16-inch hot- taps and 26-inch tie-in spools.	Transco Pipeline at SSTI	4,400	0	2nd week of Aug 2015
Flood Laterals and Mainline: 24.64 miles, 26-inch diameter x 0.52-inch w.t.	Port at CYA	3,300,000	0	3rd week of Jul 2015
Flood, Test and Dewater Buoy 1 Riser: 794-feet 14-inch diameter	Port at STL Buoy #1	6,350	6,350	3rd week of Aug 2015
Flood, Test and Dewater Buoy 2 Riser: 794-feet 14-inch diameter	Port at STL Buoy #2	6,350	6,350	3rd week of Sep 2015
Flood collocated "Y" assembly 26-inch diameter tie-in spools	Port at CYA	5,000	0	3rd week of Jul 2015
Hydrostatic pressure test of Mainline and Laterals. Assume 5% of pipeline volume is required as the additional volume needed to pressurize system.	Port at PLEMs	165,000	0	2nd week of Sep 2015
Dewater and Dry Mainline and Laterals: Vent pressurized water from hydrostatic test and dewater pipeline	Port at PLEMs	0	3,474,400	3rd week of Sep 2015
Total Hydrostatic Test Water Intake and Discharge		**3,487,100**	**3,487,100**	**--**
Notes: 1. Approximate timing based on construction schedule presented in the September 2012 DWP application.				

Table 3 – Potential LNGRV/STL Buoy Commissioning Seawater Water Intake and Discharge

Activity	Location	Vessel Type	Typical Operation and Duration	Total SW Intake (gpm)	Total SW Disch. (gpm)	CW Intake/ Disch. (gpm)	Total Operation (hrs)	Total SW Intake (MMgal)	Total SW Disch. (MMgal)	Total CW Intake/ Disch. (MMgal)	Approx. Timing
Commissioning of LNGRV and STL Buoys	Port at STL Buoys	LNGRV	Intermittent activity over a 45-day period	5,700	5,700	5,700	1080 (max.)	369.4	369.4	369.4	mid-Oct to early-Dec 2015

Notes:
1. Approximate timing based on construction schedule presented in the September 2012 DWP application.
2. Total seawater intake and discharge volumes represent maximum volumes based on continuous operation over 45 day period. LNGRV/STL Buoy commissioning related testing will be implemented intermittently during the commissioning period. Actual seawater intake/discharge volumes should be substantially less than these maximum volumes.

Table 4 – Operations Phase Seawater Intake and Discharge

Activity	Location	Vessel Type	Typical Operation and Duration	Total SW Intake (gpm)	Total SW Disch. (gpm)	CW Intake/ Disch. (gpm)	Total Annual Operation (hrs)	Total SW Intake (MMgal)	Total SW Disch. (MMgal)	Total CW Intake/ Disch. (MMgal)	Approx. Timing
LNGRV ballast water intake	Port at STL Buoys	LNGRV	24/7 for 365 days per yr.	1,338	0	0	8,760	703.4	0	0	Begins Dec 2015
Support Vessel	Port at STL Buoys	2000 HP Tug	24/7 for 365 days per yr.	883	881	881	8,760	464.0	462.8	462.8	Begins Dec 2015
Total Operations Phase Vessel Seawater Intake and Discharge								**1,167.4**	**462.8**	**462.8**	**--**

Notes:
1. Approximate timing based on construction schedule presented in the September 2012 DWP application.
2. LNGRV seawater intake flow rate is an annual average rate, based on annual average natural gas send-out of 400 MMcf/d.
3. Total support vessel seawater intake and discharge volumes conservatively assume that a support vessel will operate at the Port 24 hours per day and 365 days per year.

Table 5 – Maintenance & Repair and Emergency Scenario Seawater Intake and Discharge

Activity	Location	Vessel Type	Typical Operation and Duration	Total SW Intake (gpm)	Total SW Disch. (gpm)	CW Intake/ Disch. (gpm)	Total Operation (hrs)	Total SW Intake (MMgal)	Total SW Disch. (MMgal)	Total CW Intake/ Disch. (MMgal)	Approx. Timing
Maintenance & Repair at Hot Tap/ PLEM Riser Areas	Transco Pipeline & Port	DP Dive Support Vessel (DSV)	24/7 for 30 days	1,325	1,321	1,321	720	57.25	57.06	57.06	As needed (assume at 5 yr. intervals)
Emergency Scenario at Hot Tap/ PLEM Riser Areas	Port	DP DSV	24/7 for 30 days	1,325	1,321	1,321	720	57.25	57.06	57.06	As needed (assume at 5 yr. intervals)
Total Maintenance & Repair and Emergency Scenario Seawater Intake and Discharge								114.5	114.1	114.1	--

Notes:
1. Total seawater (SW) intake rate estimated as cooling water (CW) intake rate plus estimated potable water and miscellaneous service water demand.
2. Activities will be performed on an as needed basis. For purpose of estimating total intake and discharge over the life of the project, assume activities will be required at 5-year intervals.

Table 6 – Decommissioning Phase Seawater Intake and Discharge

Activity	Location	Vessel Type	Typical Operation and Duration	Total SW Intake (gpm)	Total SW Disch. (gpm)	CW Intake/ Disch. (gpm)	Total Operation (hrs)	Total SW Intake (MMgal)	Total SW Disch. (MMgal)	Total CW Intake/ Disch. (MMgal)	Approx. Timing
Hot Tap/PLEM Riser Areas	Transco Pipeline & Port	DP Dive Support Vessel (DSV)	24/7 for 40 days	1,325	1,321	1,321	960	76.3	76.1	76.1	End of Project Life
		2000 HP Tug	24/7 for 40 days	883	881	881	960	50.8	50.7	50.7	End of Project Life
Buoy Removal	Port	Heavy Lift Vessel	24/7 for 30 days	4	0	0	720	0.2	0	0	End of Project Life
Flood and Abandon Mainline and Laterals	Port	--	--	--	--	--	--	3.3	0	0	End of Project Life
Total Decommissioning Phase Vessel Seawater Intake and Discharge								**130.6**	**126.8**	**126.8**	--

Notes:
1. Approximate timing based on construction schedule presented in the September 2012 DWP application.
2. Total seawater (SW) intake rate estimated as cooling water (CW) intake rate plus estimated potable water and miscellaneous service water demand.
3. Heavy Lift Vessel (HLV) assumed to have closed cycle cooling and no CW intake/discharge.

Table 7 – Summary of Port Ambrose Project Estimated Seawater Intake and Discharge Volumes over Project Life

Activity	Total SW Intake (MMgal)	Total SW Disch. (MMgal)	CW Intake/ Disch. (MMgal)	Approximate Timing
One-time Limited Duration Activities				
Construction Vessels	1,862.6	1,858.2	1,858.2	February to November 2015
Hydrostatic Testing	3.5	3.5	--	August to October 2015
Deepwater Port Commissioning	369.4	369.4	369.4	October to December 2015
Decommissioning	130.7	126.8	126.8	End of Project Life
Total One-time Limited Duration Activities	**2,366.1**	**2,357.8**	**2,354.3**	
Periodic "As-needed" Activities				
Maintenance and Repair (intake/discharge over 30 days)	57.2	57.1	57.1	As needed (assume at 5 yr. intervals)
Emergency Scenario (intake/discharge over 30 days)	57.2	57.1	57.1	As needed (assume at 5 yr. intervals)
Total Periodic "As-needed" Activities	**114.5**	**114.1**	**114.1**	
Annual Operations				
DWP Operations - LNGRV and Support Vessel (total intake/discharge over a year)	**1,167.4**	**462.8**	**462.8**	Beginning in December 2015 (CW intake/discharge from support vessel only)

Notes:
1. Approximate timing based on construction schedule presented in the September 2012 DWP application.
2. Cooling water (CW) intake/discharge volumes are a subset of the total surface water (SW) intake/discharge values

Appendix K-2

Ichthyoplankton Assessment - Addendum

Environmental Report
in support of the
Port Ambrose Project Application

May 2014

Topic Report 4 – Biological Resources

Appendix D (Revised)

ICHTHYOPLANKTON ENTRAINMENT ASSESSMENT

Addendum 1:
Modeling of Supplemental Lowering of Mainline from MP 17.0 to MP 20.1

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1. Introduction

This document presents an addendum to the *Ichthyoplankton Entrainment Assessment* prepared by AECOM in January of 2014 and presented in Volume II Topic Report 4 Biological Resources Appendix D (hereafter, Appendix D) as a part of the Port Ambrose Deepwater Port application. Appendix D contains details on the entrainment model, species represented, assumptions, and data used to calculate potential impacts on fish eggs and larvae associated with seawater intake during construction, operation (including emergency actions and maintenance) and decommissioning of the Port Ambrose Project (Project). This addendum assessment only includes incremental estimates of impacts to fisheries from impingement and entrainment (I & E) related to the lowering of the Mainline pipe by an additional three feet, beyond the proposed four-foot nominal lowering, in order to achieve seven feet of cover between milepost (MP) 17 and MP 20.1. These potential additional impacts will occur during the construction period, currently envisioned between July 2016 and September 2016. Complete details of the entrainment assessment methodology and background fisheries information can be found in Appendix D.

The lowering of the Mainline pipe by an additional three feet has the potential to impact fisheries associated with the seawater intakes primarily due to entrainment. Impingement impacts from construction activities are not likely, due to the low design intake velocity proposed. The U.S. Environmental Protection Agency (EPA) has determined that an intake velocity of less than 0.5 foot per second (fps) allows most small fish to swim away from the intake (USEPA 2002). Since all water intakes related to the lowering of the pipe will use screened intakes with a velocity of less than 0.5 fps, impingement is unlikely. Therefore, the focus of this assessment is solely on entrainment impacts.

The entrainment calculations were performed following the National Oceanic and Atmospheric Administration (NOAA)/United States Coast Guard (USCG) jointly developed ichthyoplankton methodology as described in the ichthyoplankton assessment model appended to the Gulf Landing Final Environmental Impact Statement (EIS) (USCG and MARAD 2005).

The entrainment modeling used in this assessment involves estimation of the:

- density of eggs and larvae in the intake water along the pipeline route (Mainline);
- historic densities of eggs and larvae within 5 miles of the Mainline;
- numbers of organisms entrained based on estimated density and volume flow over one year;
- natural mortality rate that the entrained organisms would have otherwise undergone before reaching one year of age (i.e., estimation of Age-1 equivalents); and
- equivalent fishery yield.

Based on the modeling results and landings data, a value is estimated for the fish that may be entrained related to the lowering of the pipe. Uncertainty in the assessment is then discussed, a sensitivity analysis is performed, and the overall results of the entrainment assessment related to the pipe lowering are summarized.

2. Intake Volumes and Assumptions

In order to estimate the number of fish eggs and larvae entrained during the construction phase of the pipe lowering, estimates of the volume of water that will be withdrawn during this phase of the Project were used (Table 1). Water use on an annual basis was used for evaluation of entrainment for this assessment as it was for the entrainment assessment for the entire Project provided in Appendix D. A complete discussion of water use during all phases of the Project is provided in detail in Volume II Topic Report 3 Water and Sediment Quality, and in supplemental information provided in Appendix D.

Table 1 – Annual Increase in Water Use for the Port Ambrose Facility to Lower the Pipeline by Three Feet

Phase	Volume (M^3/year)	Intake / Discharge point	MARMAP/ECOMON data used
Pipeline Lowering Construction	994,740	Mainline	Within 5 miles of Mainline

2.1 Pipe Lowering

Entrainment impacts to ichthyoplankton due to lowering the Mainline pipe by an additional three feet during the construction period may occur as a result of water withdrawn by construction intakes including a dynamically positioned (DP) jet/tremie vessel, a hopper tug, a survey boat and the jet sled. All water will be withdrawn through screens and the intake velocity will be less than 0.5 foot per second.

3. Ichthyoplankton Density

Potential entrainment losses due to lowering the Mainline pipe by three feet during the construction period were estimated using egg and larval density estimates from MARMAP/ECOMON long-term fish monitoring projects (NMFS 2013). Plankton samples were collected during these surveys using a 61-cm bongo net fished from the surface to within 5 meters of the bottom or to a depth of 200 meters. Mesh size of the nets was 505 µm during the early surveys from 1977 to 1987 and 333 µm in later surveys. Surveys were conducted on the continental shelf from Cape Hatteras, North Carolina to Cape Sable, Nova Scotia. For this analysis only stations located within 5 miles of the Mainline were included (Figures 1 and 2).

Data for taxa that composed more than 1% of eggs or larvae collected at the selected stations and total egg and larvae abundance at those stations were obtained from NOAA (Hare 2012). Abundance data were obtained as the number under 10 m^2 sea surface area and converted to the number per 100 m^3 of volume using depth data collected during the surveys. This method assumes a uniform distribution of eggs and larvae throughout the water column, and may overestimate or underestimate abundance based on the depth preference of each species. Average annual density estimates for these taxa are included in Table 2 for eggs along the Mainline and Table 3 for larvae along the Mainline.

Data from 1977 to 2008 were used to estimate abundance. Egg data were available from 1977 to 1987, and larvae data were available from 1977 to 2008. Earlier data (1977-1987) were collected during most months and later data were collected approximately bi-monthly. Because the density of eggs and larvae is variable, the longer dataset may provide a better estimate of average density by taking into account more of the inter-annual variability. Data from the vicinity of the Project site were used to provide local estimates of density.

Figure 1 – MARMAP/ECOMON Stations Within 5 Miles of the Mainline Selected to Estimate Egg Density

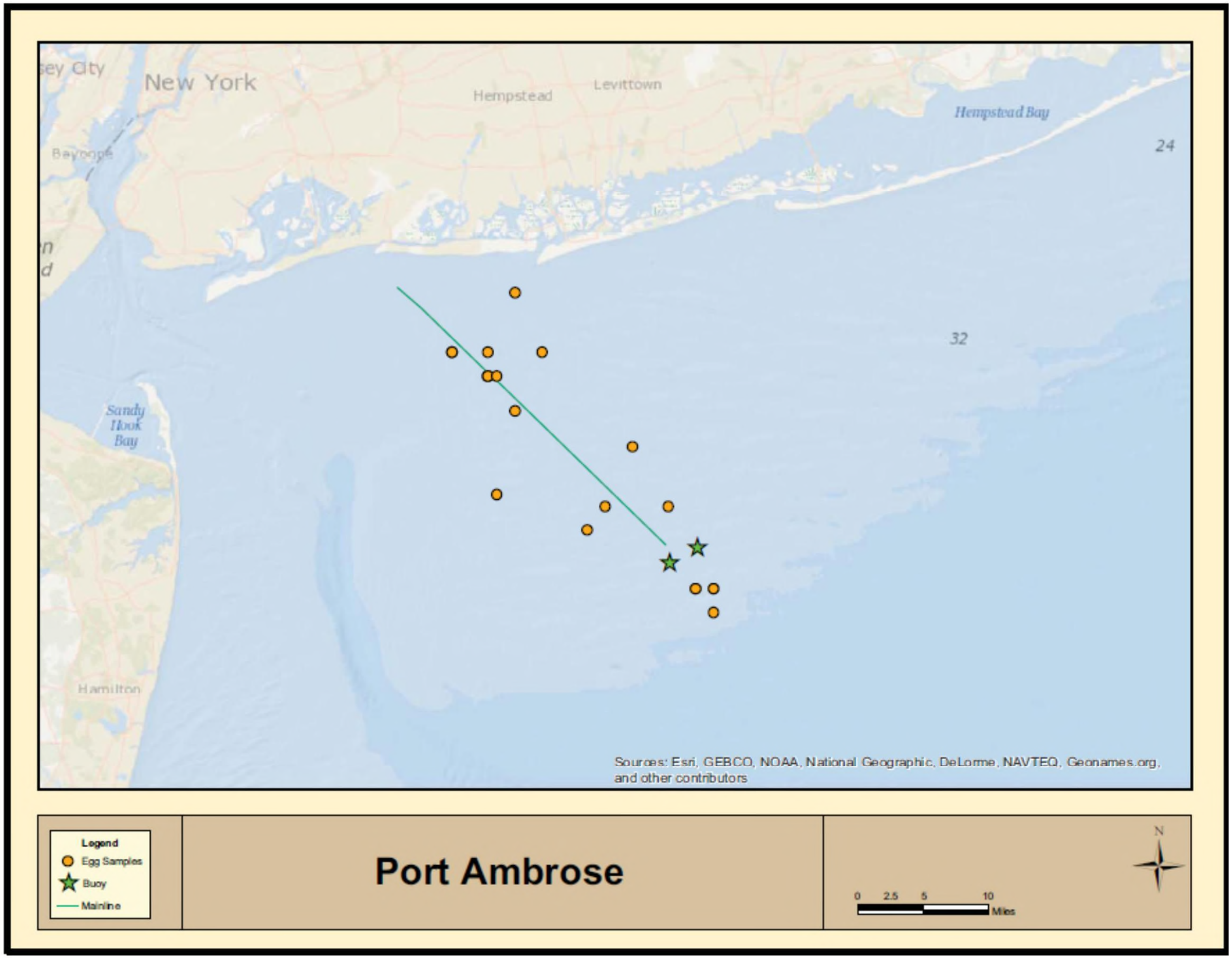

Figure 2 – Selected MARMAP/ECOMON Stations Within 5 miles of the Mainline Selected to Estimate Larvae Density

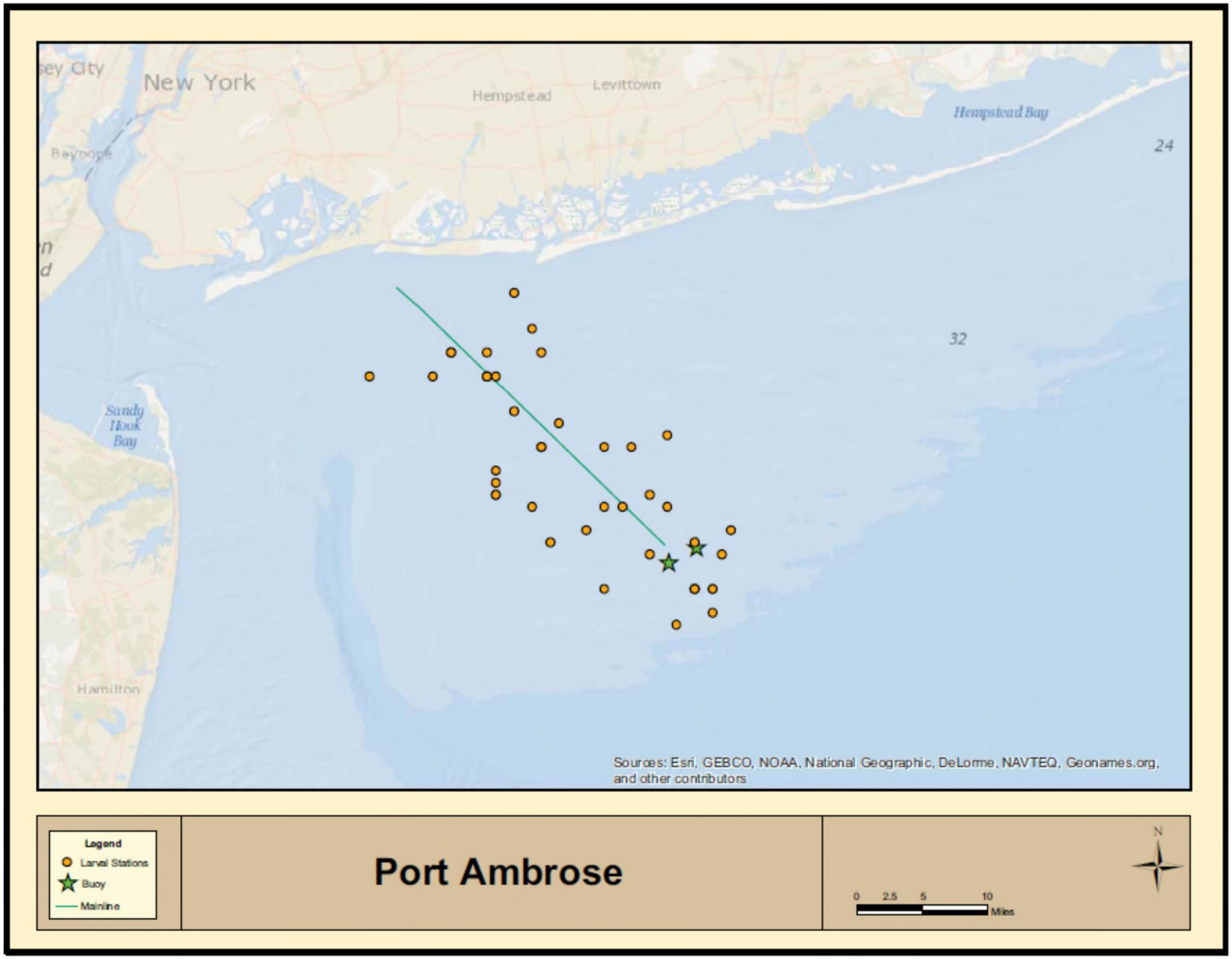

Table 2 – Estimated Annual Average Density of Eggs Along the Mainline Using the MARMAP/ECOMON Data

Taxa	Average Density[1] (#/100 m^3)
Unknown eggs	95.15
Anchovy *(Engraulidae sp.)*	9.40
Physcid hakes (red hake) (*Urophycis)*	16.23
Spotted codling (hake) *(Urophycis regia)*	
Fourbeard rockling *(Enchelyopus cimbrius)*	
Silver hake *(Merluccius bilinearis)*	
Bluefish *(Pomatomus saltatris)*	0.71
Atlantic croaker *(Micropogonias undulates)*	
Cunner *(Tautogolabrus adspersus)*	4.82
Atlantic mackerel *(Scomber scombrus)*	304.34
Butterfish *(Peprilus triacanthus)*	
Searobin *(Prionotus sp.)*	
Sand lance *(Ammodytes sp.)*	
Lefteye flounders *(Bothidae sp.)*	
Gulfstream flounder *(Citharichthys arctifrons)*	
Smallmouth flounder *(Etropus microstomus)*	
Fourspot flounder *(Hippoglossina oblonga)*	30.89
Summer flounder *(Paralicthys dentatus)*	
Yellowtail flounder *(Limanda ferruginea)*	41.51
Windowpane flounder *(Scophthalmus aquosus)*	13.00
Flounder sp *(Citharichthys)*	4.23
Total Eggs	525.30

[1]Blanks indicate that these species were not present in the catch data

Table 3 – Estimated Annual Average Density of Larvae Along the Mainline Using the MARMAP/ECOMON Data

Taxa	Average Density[1] (#/100m^3)
Unknown larvae	0.03
Anchovy *(Engraulidae sp.)*	1.34
Physcid hakes (red hake) (*Urophycis)*	5.11
Spotted codling (hake) *(Urophycis regia)*	0.48
Fourbeard rockling *(Enchelyopus cimbrius)*	0.57
Silver hake *(Merluccius bilinearis)*	0.05
Bluefish *(Pomatomus saltatris)*	
Atlantic croaker *(Micropogonias undulates)*	20.74
Cunner *(Tautogolabrus adspersus)*	0.06
Atlantic mackerel *(Scomber scombrus)*	3.45
Butterfish *(Peprilus triacanthus)*	0.72
Searobin *(Prionotus sp.)*	6.16
Sand lance *(Ammodytes sp.)*	13.28
Lefteye flounders *(Bothidae sp.)*	0.14
Gulfstream flounder *(Citharichthys arctifrons)*	1.32
Smallmouth flounder *(Etropus microstomus)*	2.14
Fourspot flounder *(Hippoglossina oblonga)*	0.88
Summer flounder *(Paralicthys dentatus)*	0.43
Yellowtail flounder *(Limanda ferruginea)*	1.9
Windowpane flounder *(Scophthalmus aquosus)*	1.17
Flounder sp *(Citharichthys)*	
Total Eggs	74.22

[1]Blanks indicate that these species were not present in the catch data

Density estimates of eggs and larvae in the vicinity of the Mainline were derived from sampling data at stations located within 5 miles of the Mainline. These data were used to evaluate potential entrainment during the lowering of the Mainline pipe by an additional three feet during construction. All available MARMAP/ECOMON data within the target area were included. These datasets included 20 sampling events for Mainline eggs and 42 sampling events for Mainline larvae. Although lowering the Mainline pipe by an additional three feet will be conducted between MP 17 and MP 20.1 in the period from July into September, there are insufficient MARMAP/ECOMON data available to perform an assessment using just data from this location and time interval. Therefore, annual average densities for the Mainline were used consistent with the data sets used in all other assessments. In order to estimate the potential maximum entrainment impact from lowering the Mainline pipe by an additional three feet, the maximum monthly densities observed were used to estimate entrainment (Section 5.3).

Density data averaged by month, and the monthly densities are included in Table 4 for eggs and Table 5 for larvae along the Mainline. Egg and larvae annual density estimates were made by taking the average of each individual sampling event within 5 miles of the Mainline for each species and for total eggs and larvae.

Table 4 – Monthly Density Estimates (#/100 m^3) for Eggs Along the Mainline

		Flounder sp	bay anchovy	physcid hakes (red hake)	silver hake	bluefish	cunner	Atlantic mackerel	fourspot flounder	yellowtail flounder	windowpane flounder	
Month	Unidentified eggs	*Citharichthys/Etropus*	*Anchoa mitchilli*	*Urophycis*	*Merluccius bilinearis*	*Pomatomus saltatrix*	*Tautogolabrus adspersus*	*Scomber scombrus*	*Hippoglossina oblonga*	*Limanda ferruginea*	*Scophthalmus aquosus*	Total
4								164.3324		101.8094	1.9612	269.1291
5	8.7714							1605.2587		66.9818		1676.9368
6	936.4695							0.4861				936.9556
7			168.0469	207.7000			93.0314		866.0388		60.6467	1396.1667
8		35.8720		18.6558		7.2150	1.1535		70.8714		1.1535	183.8085
9		2.8671		4.0981					2.1096		14.6501	22.8181
10	8.5280	0.8540		15.2803					1.9680		58.1425	81.5848

Table 5 – Monthly Density Estimates (#/100 m^3) for Larvae Along the Mainline

		anchovies	physcid hakes (red hake)	spotted codling (hake)	Fourbeard rockling	silver hake	bluefish	atlantic croaker	cunner	Atlantic mackerel	butterfish	searobin	sand lance	lefteye flounders	gulfstream flounder	smallmouth flounder	fourspot flounder	summer flounder	yellowtail flounder	windowpane flounder	flounder sp	
Month	Unidentified larvae	*Engraulidae*	*Urophycis*	*Urophycis regia*	*Enchelyopus cimbrius*	*Merluccius bilinearis*	*Pomatomus saltatrix*	*Micropogonias undulatus*	*Tautogolabrus adspersus*	*Somber scombrus*	*Peprilus triacanthus*	*Prionotus*	*Ammodytes*	*Bothidae*	*Citharichthys arctifrons*	*Etropus microstomus*	*Hippoglossina oblonga*	*Paralichthys dentatus*	*Limanda ferruginea*	*Scophthalmus aquosus*	*Citharichthys*	Total
1													1.1083									6.2343
2																						
3													4.0034									6.5502
4													45.1046						2.8912			53.6305
5					3.6923					23.7032			27.0899						8.4006	5.5227		75.8462
6					0.7339	0.4861				9.5387									4.4032			17.3635
7		17.1368									1.1421						4.5684			1.1421		27.4158
8									1.0643		1.0524	2.1286			0.5321	1.5905	3.7250					12.7476
9	0.1287	2.9553	18.3119	1.9878	0.3214			85.5469			2.5535	24.8698		0.3750	5.3216	7.5715	1.7302	1.1563		0.1287		189.5698
10			10.3853			0.3905								0.7810		3.5143	1.5619	1.4043		5.1516		60.1253
11		3.3333	1.3333															2.0000		4.0000		14.0000

4. Model Inputs and Results for Taxa of Concern

The MARMAP/ECOMON data collected within 5 miles of the Mainline were used to evaluate the pipe lowering. The data used in this addendum cover a range of years and months and has the advantage of having multiple survey events in the specific project area. However, these data do have some limitations. For example, eggs and larvae can be difficult to differentiate to species level. As a result, individuals that may have been misidentified and/or not identified to species level may not be included in the species-specific density estimates. Conversely, species misidentified may have been included in the density estimates for the wrong species.

These data limitations are compounded by the fact that data regarding ichthyoplankton abundance and distribution are themselves highly variable or patchy. This patchiness derives from the natural variability of environmental influences such as water temperature, hydrographic features, spawning events, and migration patterns. Additionally, the natural mortality of fish is also highly variable and depends on factors such as predation, starvation, weather, and location. Natural mortality varies among species and is greatest during early life-history stages (EPA 2002). Natural mortality can be as high as 96 percent for larvae and 99 percent for eggs (Houde 1987), and only a small percentage of newly hatched eggs or larvae typically survive to adulthood.

Entrainment impacts from pipeline lowering during construction are calculated by multiplying the ichthyoplankton egg and larvae densities along the Mainline by the expected water withdrawal during the pipeline lowering phase. Estimates of entrainment during pipeline lowering are shown in Table 6.

Life history data (stage specific mortality) for all species were obtained from Case Studies included in EPA (2002) and used to determine the Age-1 equivalents and are presented in AECOM (2014). The estimated number of Age-1 equivalents that would be entrained during pipeline lowering is shown in Table 7.

Table 6 – Entrainment Estimates Derived from Annual Average Egg and Larvae Densities (number/yr)

Species	Entrainment During Pipeline Lowering During Construction	
	Eggs	Larvae
Unknown (eggs and larvae)	946,450	310
Anchovy *(Engraulidae sp.)*	93,539	13,297
Physcid hakes (red hake) (*Urophycis)*	161,411	50,822
Spotted codling (hake) *(Urophycis regia)*		4,794
Fourbeard rockling *(Enchelyopus cimbrius)*		5,669
Silver hake *(Merluccius bilinearis)*		528
Bluefish *(Pomatomus saltatris)*	7,098	
Atlantic croaker *(Micropogonias undulates)*		206,296
Cunner *(Tautogolabrus adspersus)*	47,897	642
Atlantic mackerel *(Scomber scombrus)*	3,027,367	34,331
Butterfish *(Peprilus triacanthus)*		7,137
Searobin *(Prionotus sp.)*		61,257
Sand lance *(Ammodytes sp.)*		132,125
Lefteye flounders *(Bothidae sp.)*		1,375
Gulfstream flounder *(Citharichthys arctifrons)*		13,154
Smallmouth flounder *(Etropus microstomus)*		21,336
Fourspot flounder *(Hippoglossina oblonga)*	307,256	8,737
Summer flounder *(Paralicthys dentatus)*		4,238
Yellowtail flounder *(Limanda ferruginea)*	412,955	18,884
Windowpane flounder *(Scophthalmus aquosus)*	129,272	11,625
Flounder sp *(Citharichthys)*	42,085	
Total	**5,175,331**	**596,555**

Table 7 – Annual Age-1 Equivalents for Eggs and Larvae Entrained from Three-Foot Pipeline Lowering During Construction of the Facility

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Unknown			946,450	310			
Anchovy *(Engraulidae sp.)*	4.6587E-05	0.000186402	93,539	13,297	4.4	2.5	6.9
Physcid hakes (red hake) (*Urophycis)*	4.48155E-06	1.96372E-05	161,411	50,822	0.7	1.0	1.7
Spotted codling (hake) *(Urophycis regia)*	4.48155E-06	1.96372E-05		4,794		0.1	0.1
Fourbeard rockling *(Enchelyopus cimbrius)*	0.001040142	0.011254173		5,669		63.8	63.8
Silver hake *(Merluccius bilinearis)*	5.28094E-06	2.7312E-05		528	0.0	0.0	0.0
Bluefish *(Pomatomus saltatris)*	6.42846E-07	3.12175E-06	7,098		0.0		0.0
Atlantic croaker *(Micropogonias undulates)*	0.001488948	0.003721474		206,296		767.7	767.7
Cunner *(Tautogolabrus adspersus)*	0.00017922	0.005739314	47,897	642	8.6	3.7	12.3
Atlantic mackerel *(Scomber scombrus)*	4.18282E-06	4.95845E-05	3,027,367	34,331	12.7	1.7	14.4
Butterfish *(Peprilus triacanthus)*	9.53079E-05	0.001044561		7,137		7.5	7.5
Searobin *(Prionotus sp.)*	0.001876404	0.020075405		61,257		1,229.7	1,229.8
Sand lance *(Ammodytes sp.)*	0.001107888	0.005370236		132,125		709.5	709.5
Lefteye flounders *(Bothidae sp.)*	1.83607E-05	9.3479E-05		1,375		0.1	0.1

Species	Egg Fraction Surviving to Age-1	Larvae Fraction Surviving to Age-1	Egg Entrainment	Larvae Entrainment	Egg Age-1 Equiv	Larvae Age-1 Equiv	Total Age-1 Equiv
Gulfstream flounder *(Citharichthys arctifrons)*	1.83607E-05	9.3479E-05		13,154		1.2	1.2
Smallmouth flounder *(Etropus microstomus)*	1.83607E-05	9.3479E-05		21,336		2.0	2.0
Fourspot flounder *(Hippoglossina oblonga)*	1.83607E-05	9.3479E-05	307,256	8,737	5.6	0.8	6.4
Summer flounder *(Paralicthys dentatus)*	1.83607E-05	9.3479E-05		4,238		0.4	0.4
Yellowtail flounder *(Limanda ferruginea)*	1.83607E-05	9.3479E-05	412,955	18,884	7.6	1.8	9.4
Windowpane flounder *(Scophthalmus aquosus)*	1.83607E-05	9.3479E-05	129,272	11,625	2.4	1.1	3.5
Flounder sp *(Citharichthys)*	1.83607E-05	9.3479E-05	42,085		0.8		0.8
Total (excluding unknown)							2837.4

5. Forgone Fishery Yield

Foregone fishery yield is a measure of the amount of fish or shellfish (in pounds) that is not harvested because the fish are lost to impingement and entrainment. The model involves multiplying age-specific harvest rates by age-specific weights to calculate age-specific expected yields (in pounds). The model assumes that the yield from a cohort of fish is proportional to the number recruited; the annual growth, natural mortality, and fishing mortality rates are known and constant; and natural mortality includes mortality due to impingement and entrainment (I&E).

The lifetime expected yield for a cohort of fish is the sum of all age-specific expected yields:

$$Y = \sum \sum N_j * S_{ja} * W_a * (1\text{-exp}(-Z_a)) * (F_a / Z_a)$$

Where:

Y = forgone yield (in pounds) due to I & E losses

N_j = number of individuals lost from stage j

S_{ja} = cumulative survival from stage j to stage a

W_a = average weight (pounds) of fish at stage a

F_a = instantaneous annual fishing mortality rate for fish of stage a

Z_a = instantaneous annual total mortality rate for fish of stage a

Forgone fishery yield for the estimated annual entrainment from lowering the pipeline by three feet was calculated for each of the selected species and is included in Table 8.

Table 8 – Estimated Annual Forgone Fishery Yield from Three-Foot Pipe Lowering During Construction

Species	Three-Foot Pipe Lowering During Construction Annual Forgone Fishery Yield (pounds)
Unknown	
Anchovy (*Engraulidae sp.*)	
Physcid hakes (red hake) (*Urophycis*)	0.5
Spotted codling (hake) (*Urophycis regia*)	
Fourbeard rockling (*Enchelyopus cimbrius*)	
Silver hake (*Merluccius bilinearis*)	
Bluefish (*Pomatomus saltatris*)	
Atlantic croaker (*Micropogonias undulates*)	156.7
Cunner (*Tautogolabrus adspersus*)	0.1
Atlantic mackerel (*Scomber scombrus*)	2.2
Butterfish (*Peprilus triacanthus*)	0.2
Searobin (*Prionotus sp.*)	51.2

Species	Three-Foot Pipe Lowering During Construction Annual Forgone Fishery Yield (pounds)
Sand lance (*Ammodytes sp.*)	
Lefteye flounders (*Bothidae sp.*)	
Gulfstream flounder (*Citharichthys arctifrons*)	
Smallmouth flounder (*Etropus microstomus*)	0.1
Fourspot flounder (*Hippoglossina oblonga*)	0.1
Summer flounder (*Paralicthys dentatus*)	0.0
Yellowtail flounder (*Limanda ferruginea*)	0.2
Windowpane flounder (*Scophthalmus aquosus*)	0.1
Flounder sp (*Citharichthys*)	
Total (*excluding unknown*)	211.5

5.1 Value

Commercial and recreational fishing statistics for New York were used to provide a value estimate for fish that may be entrained during construction and operation of the facility. Total annual landings for New York from 2003 to 2012 for commercial fisheries and 2003 to 2012 for recreational fisheries were obtained from the National Marine Fisheries Service (NMFS) Annual Landings data (NMFS 2013) and are used to provide estimated annual landings for each species considered in this analysis. Table 9 includes the average annual commercial and recreational landings data.

Price per pound for commercial fisheries and an estimated value per fish for recreational fisheries are also included in Table 9. Commercial prices were obtained from NMFS landings data, and recreational values were estimated by EPA in a benefits analysis for the proposed Clean Water Act Section 316(b) rule. These data can be used to provide an estimated value for the fish entrained.

In addition to recreational and commercial value, fish also have indirect and non-use values. Indirect values are generally considered for forage fish and non-use values are the intrinsic value that a resource has in the public opinion. These values are hard to quantify. Due to the limitations and uncertainties involved in calculating indirect and non-use values as well as the fact that most of the species included in this study have recreational and/or commercial value, these values have not been included in this analysis.

The commercial value of the forgone fishery yield calculated for each of the selected species is included in Table 10.

Table 9 – Average Annual Landings

Species	Commercial[2] (years of reported data in parentheses)	Recreational[3,4] (years of reported data in parentheses)	Commercial ($ per lb)[1]	Recreational ($ per individual fish)[5]
Unknown				
Anchovy *(Engraulidae sp.)*				$2.91
Physcid hakes (red hake) (*Urophycis)*		31,329 (10)		$2.91
Spotted codling (hake) *(Urophycis regia)*				$2.91
Fourbeard rockling *(Enchelyopus cimbrius)*				$2.91
Silver hake *(Merluccius bilinearis)*				$2.91
Bluefish *(Pomatomus saltatris)*	1,2245,411 (10)	4,359,534 (9)	$0.48	$2.91
Atlantic croaker *(Micropogonias undulates)*	4,668 (10)		$0.75	$2.91
Cunner *(Tautogolabrus adspersus)*	5,237 (10)	1,395 (9)	$3.88	$2.91
Atlantic mackerel *(Scomber scombrus)*	127,677 (10)	11,295 (4)	$0.47	$2.91
Butterfish *(Peprilus triacanthus)*	391,497 (10)		$0.81	$2.91
Searobin *(Prionotus sp.)*	24,880 (9)		$0.21	$2.91
Sand lance *(Ammodytes sp.)*				$2.91
Lefteye flounders *(Bothidae sp.)*				$5.60
Gulfstream flounder *(Citharichthys arctifrons)*				$5.60
Smallmouth flounder *(Etropus microstomus)*				$5.60
Fourspot flounder *(Hippoglossina oblonga)*	14,415 (7)	413 (5)	$0.39	$5.60
Summer flounder *(Paralicthys dentatus)*	1,274,351 (10)	2,562,653 (10)	$2.57	$5.60
Yellowtail flounder *(Limanda ferruginea)*	55,362 (10)		$1.55	$5.60

Species	Commercial[2] (years of reported data in parentheses)	Recreational[3,4] (years of reported data in parentheses)	Commercial ($ per lb)[1]	Recreational ($ per individual fish)[5]
Windowpane flounder *(Scophthalmus aquosus)*	61,884 (10)	152 (10)	$0.57	$5.60
Flounder sp *(Citharichthys)*				$5.60

[1]Blank cells had no catch data reported between 2003 and 2012

[2]Commercial Landings data for NY, average lb/year and $/lb from 2003 to 2012. Source: NOAA Annual Commercial Landings Statistics (NMFS 2013).

[3]Recreational Landings data for NY, average lb/year from 2003 to 2012. Source: NOAA NMFS, Fisheries Statistics (NMFS 2013).

[4]Records without recorded weights were not included.

[5]Recreational Values are from Environmental and Economic Benefits Analysis for Proposed Section 316(b) Existing Facilities Rule. Winter and summer flounder were estimated in this report and used for all flounders; all other species have the value reported for other saltwater species. (EPA, 2011).

Table 10 – Estimated Annual Forgone Fishery Yield from Commercial Value Attributed to Additional Three-Foot Pipeline Lowering during Construction

Species	Construction Annual Forgone Fishery Yield Commercial Value
Unknown	
Anchovy (*Engraulidae sp.*)	
Physcid hakes (red hake) (*Urophycis*)	
Spotted codling (hake) (*Urophycis regia*)	
Fourbeard rockling (*Enchelyopus cimbrius*)	
Silver hake (*Merluccius bilinearis*)	
Bluefish (*Pomatomus saltatris*)	
Atlantic croaker (*Micropogonias undulates*)	\$117.64
Cunner (*Tautogolabrus adspersus*)	\$0.26
Atlantic mackerel (*Scomber scombrus*)	\$1.04
Butterfish (*Peprilus triacanthus*)	\$0.17
Searobin (*Prionotus sp.*)	\$10.52
Sand lance (*Ammodytes sp.*)	
Lefteye flounders (*Bothidae sp.*)	
Gulfstream flounder (*Citharichthys arctifrons*)	
Smallmouth flounder (*Etropus microstomus*)	
Fourspot flounder (*Hippoglossina oblonga*)	\$0.05
Summer flounder (*Paralicthys dentatus*)	\$0.02
Yellowtail flounder (*Limanda ferruginea*)	\$0.28
Windowpane flounder (*Scophthalmus aquosus*)	\$0.04
Flounder sp (*Citharichthys*)	
Total (excluding unknown)	\$130.03

5.2 Uncertainty

The models used in this analysis simplify very complex processes. This inherent simplification can lead to inaccuracies in the final results. Examples of sources of uncertainty in the process include: eggs and larvae are difficult to identify to the species level and therefore species totals in the MARMAP/ECOMON data may underestimate or overestimate the densities, especially for particularly hard to identify species; only recreational and commercial values are considered, and non-use or indirect values are not included; life history values are considered constant; market values of fish are also assumed constant; landings of commercial and recreational fish are assumed to be within the state where the facility will be located; egg and larval densities are assumed to be constant over space, depth, and time; entrainment survival is assumed to be zero; and all age-1 fish are valued as if they were harvested.

This analysis is intended to be an estimate of entrainment losses of species that may occur from construction activities and to provide some quantification of the value of that loss. However, it does provide a reasonably conservative estimate of the magnitude of the loss of fish to entrainment.

5.3 Sensitivity Analysis

Because of the uncertainties described above, especially the variability in ichthyoplankton densities, a sensitivity analysis was used to provide a range of entrainment using the variation in monthly densities of eggs and larvae. Ichthyoplankton densities are variable both spatially and temporally, dependent upon such things as spawning behavior, currents, and weather. The use of minimum and maximum monthly densities can give an estimate of this variability. Because of the limited MARMAP/ECOMON data available within 5 miles of the Mainline, each species potentially entrained was not encountered for at least one month. Therefore the minimum entrainment estimate based on the minimum monthly density for each species is zero. Estimated annual entrainment maximum densities are shown in Table 11.

Table 11 – Entrainment Estimates Attributable to Three-Foot Lowering of Pipe Based on Maximum Monthly Densities

Species	Entrainment from Three Foot Lowering of Pipe During Construction	
	Eggs	Larvae
Unknown (eggs and larvae)	9,315,437	1,280
Anchovy *(Engraulidae sp.)*	1,870,774	170,467
Physcid hakes (red hake) (*Urophycis)*	2,066,075	182,156
Spotted codling (hake) *(Urophycis regia)*		19,773
Fourbeard rockling *(Enchelyopus cimbrius)*		36,729
Silver hake *(Merluccius bilinearis)*		4,836
Bluefish *(Pomatomus saltatris)*	70,980	
Atlantic croaker *(Micropogonias undulates)*		850,969
Cunner *(Tautogolabrus adspersus)*	935,387	10,587
Atlantic mackerel *(Scomber scombrus)*	16,364,972	235,785
Butterfish *(Peprilus triacanthus)*		25,401
Searobin *(Prionotus sp.)*		247,390
Sand lance *(Ammodytes sp.)*		448,673
Lefteye flounders *(Bothidae sp.)*		7,768
Gulfstream flounder *(Citharichthys arctifrons)*		52,936
Smallmouth flounder *(Etropus microstomus)*		75,317
Fourspot flounder *(Hippoglossina oblonga)*	4,635,820	45,444
Summer flounder *(Paralicthys dentatus)*		19,895

Species	Entrainment from Three Foot Lowering of Pipe During Construction	
	Eggs	Larvae
Yellowtail flounder *(Limanda ferruginea)*	1,013,674	83,564
Windowpane flounder *(Scophthalmus aquosus)*	883,992	54,937
Flounder sp *(Citharichthys)*	378,707	
Total	37,535,818	2,573,906

Comparison of the maximum entrainment densities in Table 11 to the average entrainment densities in Table 6 provides an indication of the range of entrainment losses that may occur. The estimate of total entrainment using maximum densities, a hypothetical worst case scenario, is approximately 8 times greater for eggs and 4 times greater for larvae than the estimate using average densities. However, due to the high rates of mortality associated with these life stages, this still represents a minor impact to the fishery.

6. Summary

Estimated entrainment from the three foot pipe lowering portion of the construction phase of the Mainline is 5,175,331 eggs and 596,555 larvae of fish. These eggs and larvae combined are equivalent to 2,837 Age-1 fish. This compares to a loss of 24,138 Age-1 equivalent fish during construction without the three foot lowering (AECOM 2014). The potential increase in entrainment caused by lowering the pipe by an additional three feet represents an 11.8% increase in the entrainment during construction and this increase equates to approximately 212 pounds of foregone fishery yield with a value of $130. This equates to a very small percentage (much less than 1%) of the annual commercial and recreational fishery harvest.

Entrainment impacts from lowering the Mainline pipe by an additional three feet are expected to be minimal due to its location in a low-productivity, off-shore area and its relatively limited water withdrawals.

7. References

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